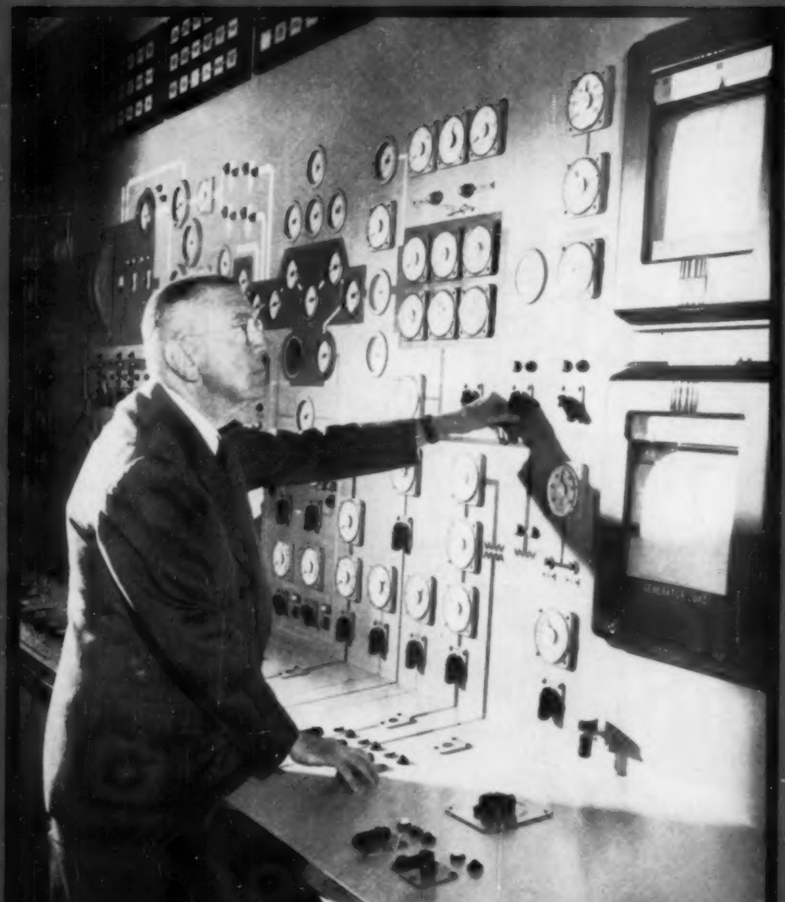
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

December 1956



E. F. Barrett, Chairman, Long Island Lighting Co., at the control board of the new station recently named in his honor.

Power Maintenance Costs

Engineering Eddystone Steam Generator

ASME Annual Meeting Highlights

Water Treatment for Boilers

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 28 **No. 6**

December 1956

Feature Articles

Editorials

Departments

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BPA

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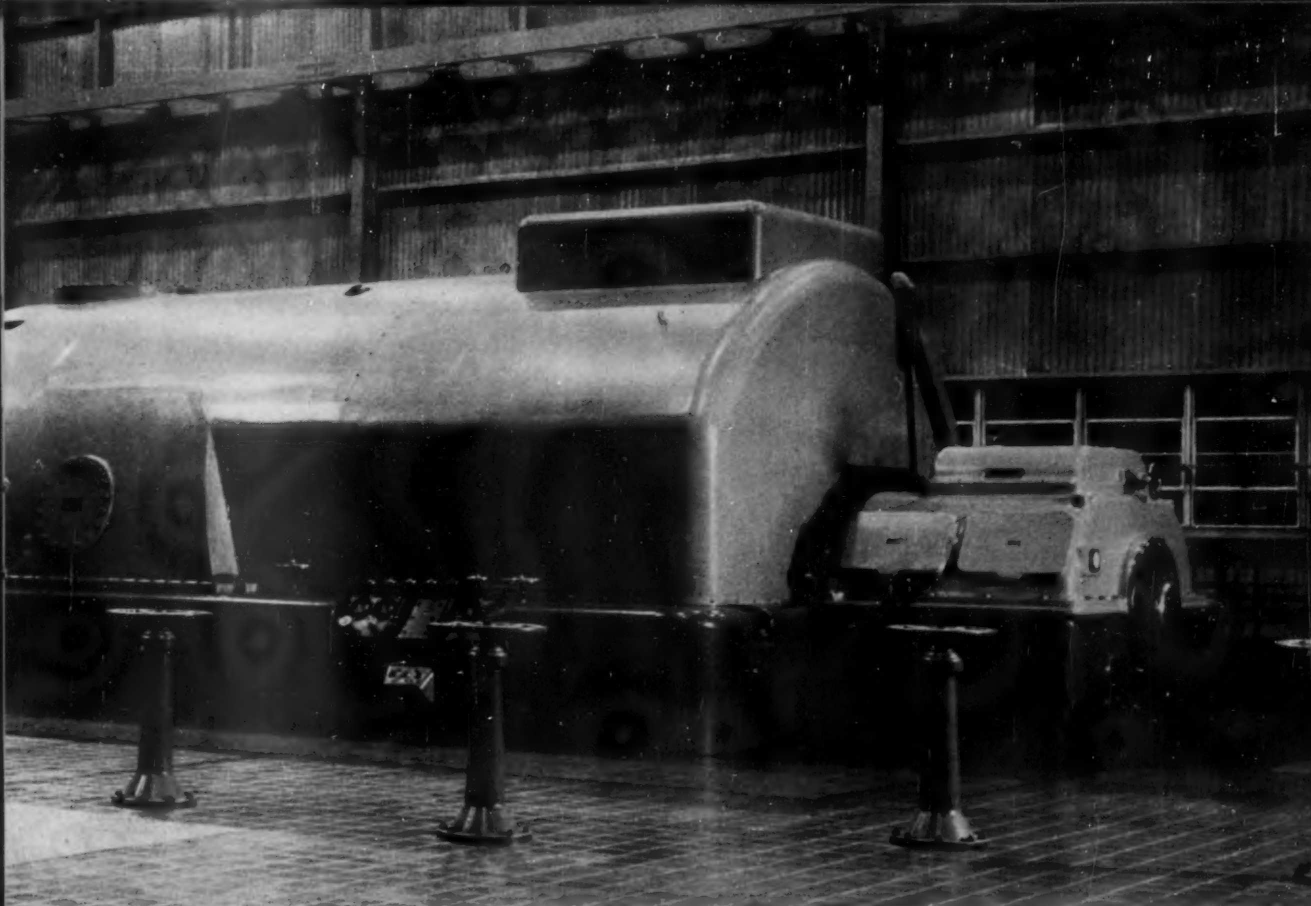
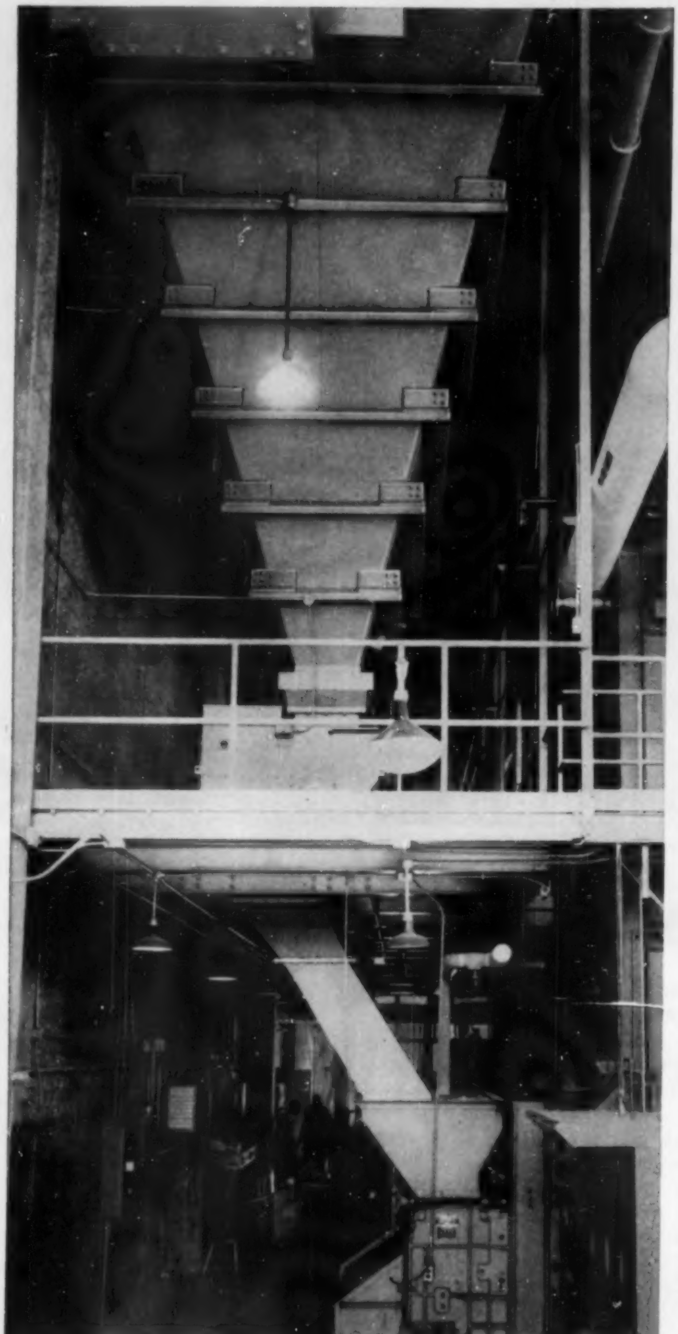




One more new installation of Lukens Type 304 *stainless-clad* steel — these smooth-operating coal hoppers and chutes, fabricated by Fairfield Engineering Company, Marion, Ohio, feed through second-floor scales to boiler.

Clad Steel Chosen Again...

STEADY COAL FLOW A MUST IN NEW STATE HOSPITAL PLANT!

Hospitals can't take a chance on power interruptions from coal hangups. In Wisconsin's Mendota State Hospital, three *stainless-clad* steel coal hoppers and chutes, three-stories high, assure smooth, dependable coal flow. In more and more coal handling installations, clad steel is being specified because of these *demonstrated* advantages:

- Substantial economies from lower maintenance costs in chutes, hoppers, bunkers, pipes and spreaders.
- Freedom from hangups and the damaging and costly effects of sulfuric acid corrosion from wet coal.
- Toughness proved by *installations 10 years old which showed no measurable wear!*
- Evidence of service life that matches the life of the boiler!

PLUS: ready fabrication . . . permanence of bond between stainless steel cladding and strong, low-cost carbon steel backing . . . over-all quality that delivers lower maintenance costs, longer life, and trouble-free operation.

Bulletin 740 will give you performance facts and product information to help your engineers make the most of clad steel. For this bulletin, as well as the names of some of the nation's best and most experienced coal handling equipment builders, write Manager, Marketing Service, 845 Lukens Building, Lukens Steel Company, Coatesville, Pa.

STAINLESS-CLAD STEELS

LUKENS

FOR INTERIOR COAL HANDLING EQUIPMENT

LUKENS STEEL COMPANY, COATESVILLE, PENNSYLVANIA

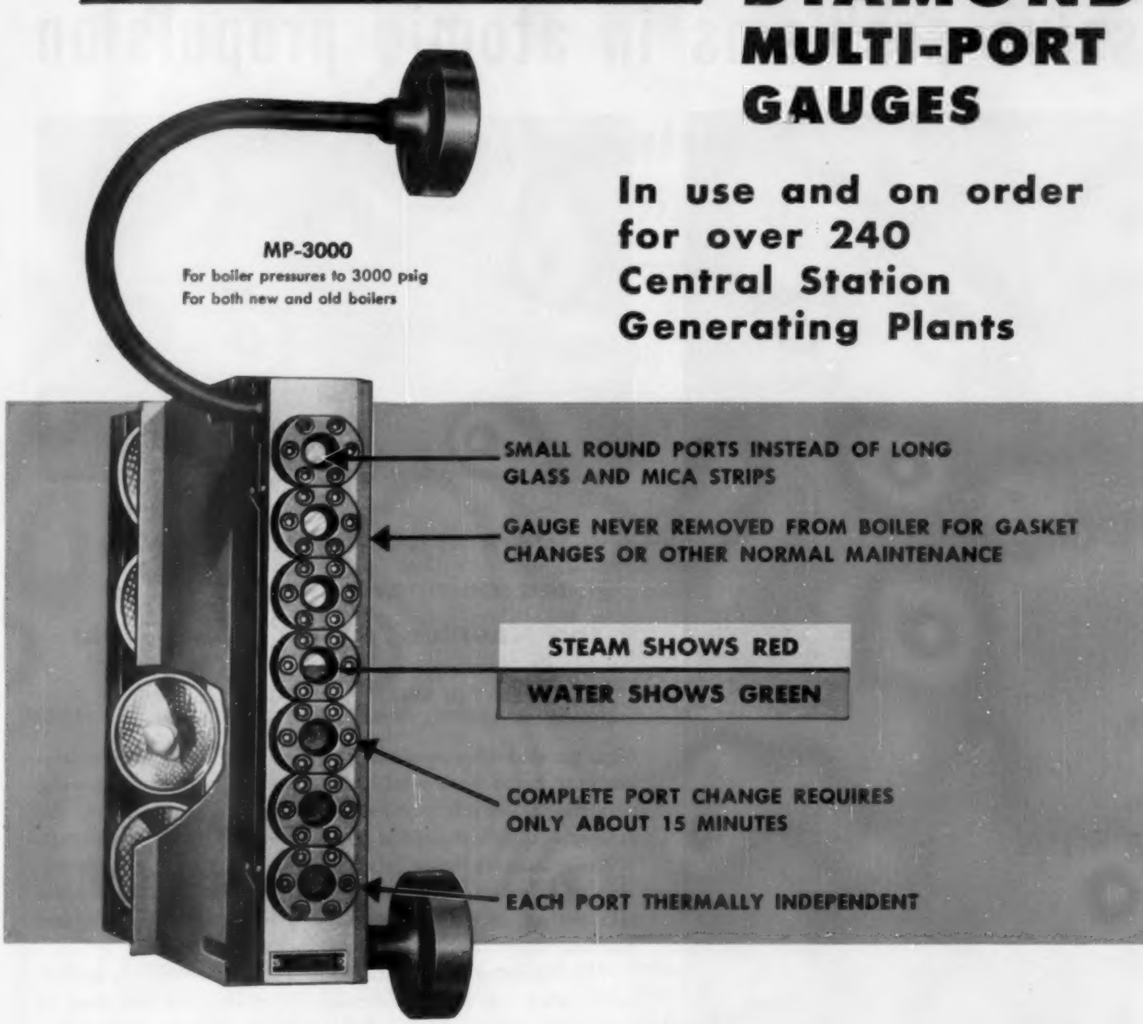
Producers of the Widest Range of Types and Sizes of Clad Steel Available Anywhere

MORE THAN 950

DIAMOND MULTI-PORT GAUGES

In use and on order for over 240 Central Station Generating Plants

MP-3000
For boiler pressures to 3000 psig
For both new and old boilers



Because the Diamond Multi-Port solves the problems inherent in water level gauges on boilers operating at high temperatures and pressures, it has had rapid and wide acceptance. In addition to the 950 for central station generating plants, more than 100 have been sold to industrial power plants.

Advantages of the Multi-Port are many. In addition to those shown above, it has maximum thermal stability for rapid starting . . . "Hi-Lite" illuminator for improved readability . . . welded construction for permanent tightness . . . end stems can be furnished instead of flanges . . . startling reductions in maintenance costs.

Write for Bulletin 1174V for more information.

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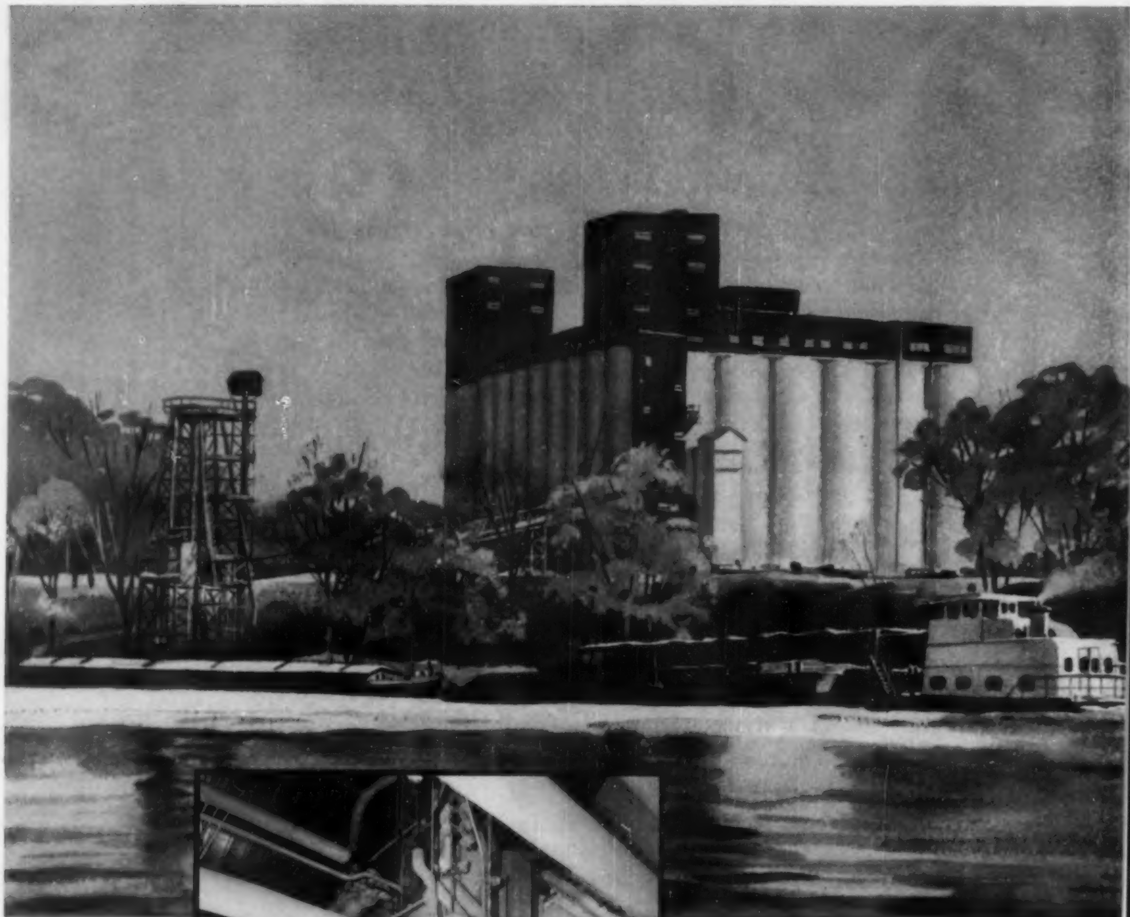
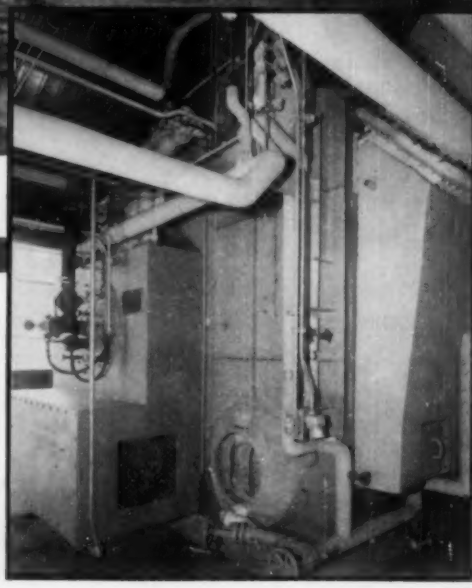




From an original water color of the Central Soya Co., Inc.—McMillen Feed Mills—by Kent Day Coes. Commissioned by "Factory" magazine for their 1956 Significant Plant Awards.

C-E Package Boiler, Type VP which supplies all steam requirements. Capacity 40,000 lb of steam per hr, operating pressure — 155 psi. Gas fired.

—LOW ON MAINTENANCE"

Says Mr. Max R. Spencer — Superintendent
Central Soya Co., Inc. — McMillen Feed Mills

"Our package boiler, after 18 months of operation, has proven to be very reliable, economical and low on maintenance costs. Ease of start-up, shut-down and continuous operation permitted quick training for our operators."

Mr. Max R. Spencer, Maintenance Superintendent of the Central Soya Co., Inc. — McMillen Feed Mills — of Chattanooga, Tenn., was referring to his C-E Package Boiler, Type VP, when he made that statement.

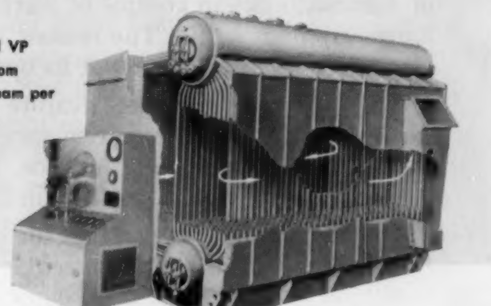
It's a boiler that has to be good — has to be reliable — for it is presently the sole source of steam supply for this outstanding plant. And it *is* an outstanding plant having been named one of "The 1956 Winners of Factory's Significant Plant Awards".

Central Soya is a real, modern "triple threat" operation. It comprises: (1) mammoth new grain-handling elevators, (2) feed mill, and (3) soybean solvent extraction plant all integrated into a smoothly operating "continuous process" plant that is expandable and ready for any foreseeable need.

Combustion Engineering is proud that its VP Package Boiler has been assigned a key role in the operating plan of this notable mill. Gratified, too, that it is proving to be all that Mr. Spencer had hoped for.

A C-E Package Boiler, Type VP can do the same kind of a job for you. Let us give you more information.

Cutaway view of typical VP Boiler. For capacities from 4,000 to 40,000 lb of steam per hr. Pressures to 500 psi. Oil or gas fuel.



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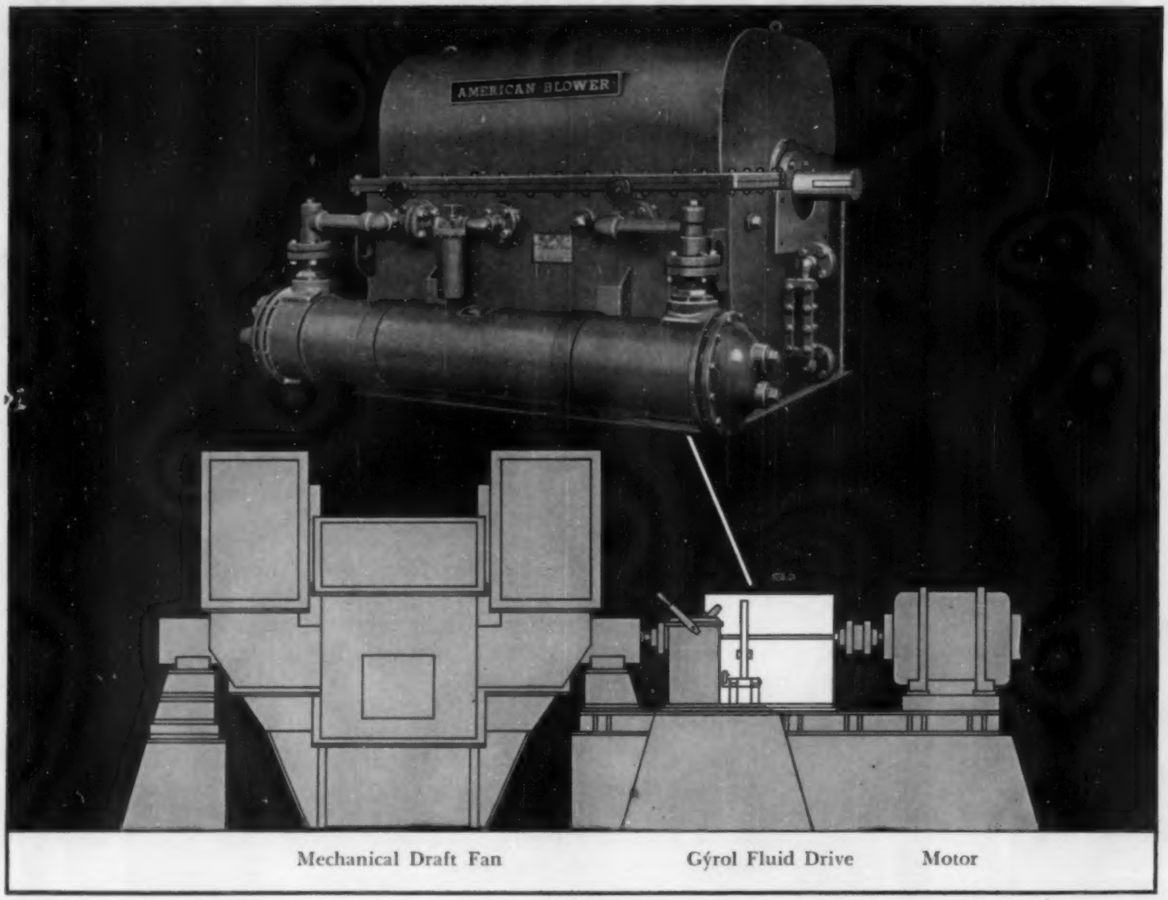
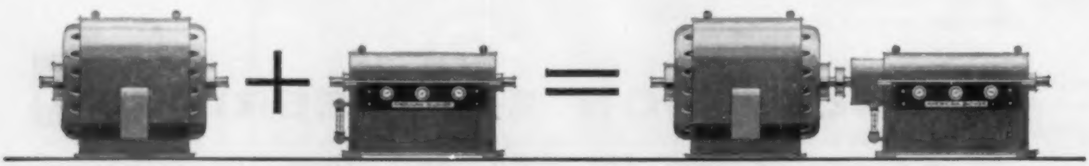
The tougher the duty, the more



LARGER MECHANICAL DRAFT FANS – Gýrol Fluid Drive gives you the kind of accurate, efficient control of mechanical draft that results in important power savings, longer equipment life. The reason: Fluid Drive's infinitely adjustable speed control, which enables each fan to operate at its optimum design or selection point.

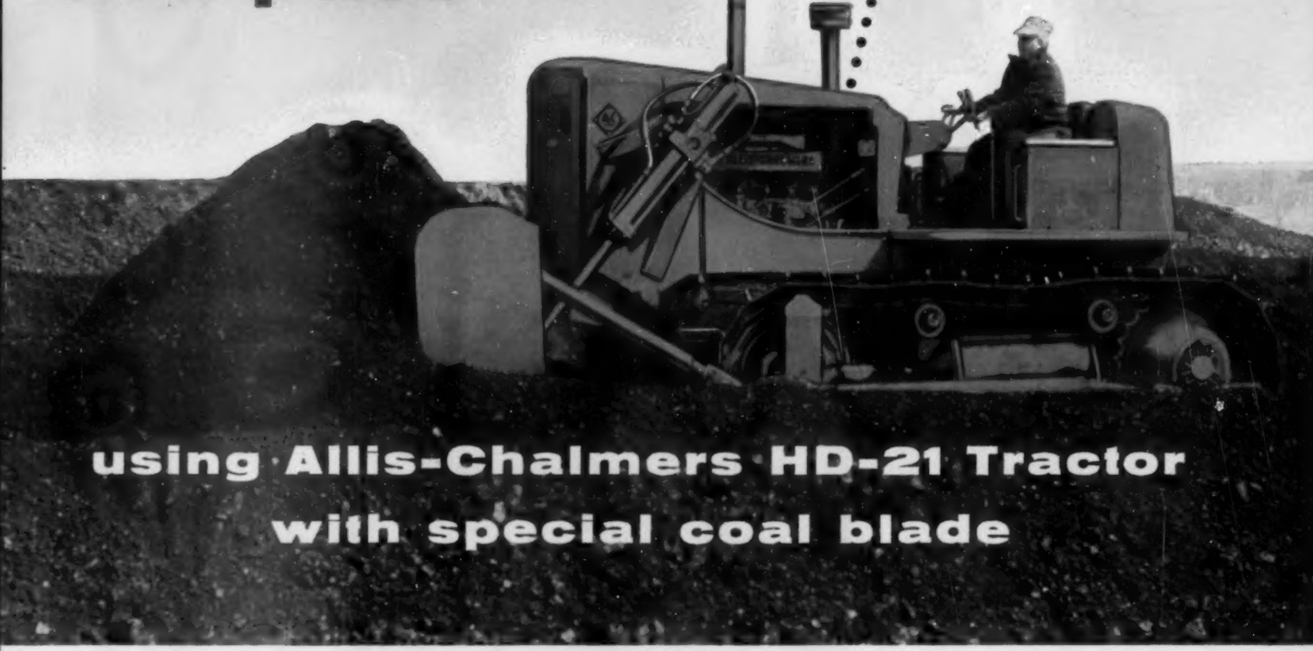
This adjustable-speed feature saves horsepower, gives good, stable volume and pressure control over the operating range . . . simplifies motor-starting equipment . . . reduces damaging high- and long-duration inrush currents on the motors . . . provides no-load starting of high WR²s that exist in the new, high-volume, high-pressure fan wheels.

What's more, it prolongs life of fan bearings; reduces fly-ash abrasion on fan wheel, fan scroll, inlet boxes, and breeching connections. When you add to these advantages the reduction in noise level, it becomes increasingly clear that the tougher the duty, the more you need Gýrol Fluid Drive for control of mechanical draft.



Rugged constant-speed induction motor + American Blower Gýrol Fluid Drive = Smooth, adjustable-speed control

Move 15 tons at a pass . . .



using Allis-Chalmers HD-21 Tractor with special coal blade

A special coal-handling blade now available for the Allis-Chalmers HD-21 fully uses the tremendous power and weight of this big tractor to move 15 tons of coal at a time.

HD-21 is coal-handling specialist— With its 204-hp diesel engine, the HD-21 has plenty of power for moving big loads. The hydraulic torque converter drive multiplies drawbar pull up to four and a half times, automatically accelerates to the highest traveling speed conditions permit. The torque converter permits climbing steeper grades, prevents killing the engine or digging in at soft spots, eliminates effort and time lost in shifting.

The compacting effect of a crawler tractor is well known. Through repeated trips over the coal pile, the 26-ton HD-21 and blade eliminate voids, prevent spontaneous combustion. The blade is shaped to move coal easily with a minimum of coal separation.

Dependability of the HD-21 is assured by Allis-Chalmers advanced design — Box-A Type Main Frame, one-piece steering clutch and final drive housing, straddle-mounted final drive gears, roller bearing truck wheels, through-hardened track rails — which also mean long life, less maintenance and faster repair when necessary.

Allis-Chalmers HD-21 tractor has 204 net engine hp, weighs 26 tons complete with cable or hydraulically controlled blade. Special coal blade has extra 56½-in. height and 15-ft length, plus boxed-in ends to carry 15 tons or more at a pass.

For additional information about the HD-21 tractor and coal blade — or about the other Allis-Chalmers tractors, tractor shovels, scrapers and motor scrapers — see your Allis-Chalmers construction machinery dealer or write direct to the company.

A-C ALLIS-CHALMERS

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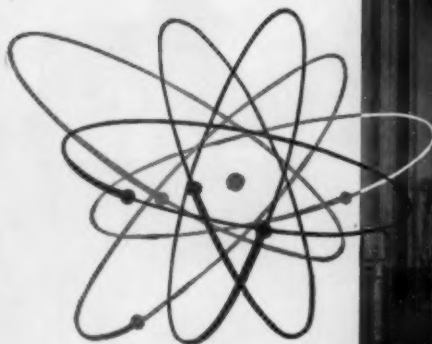

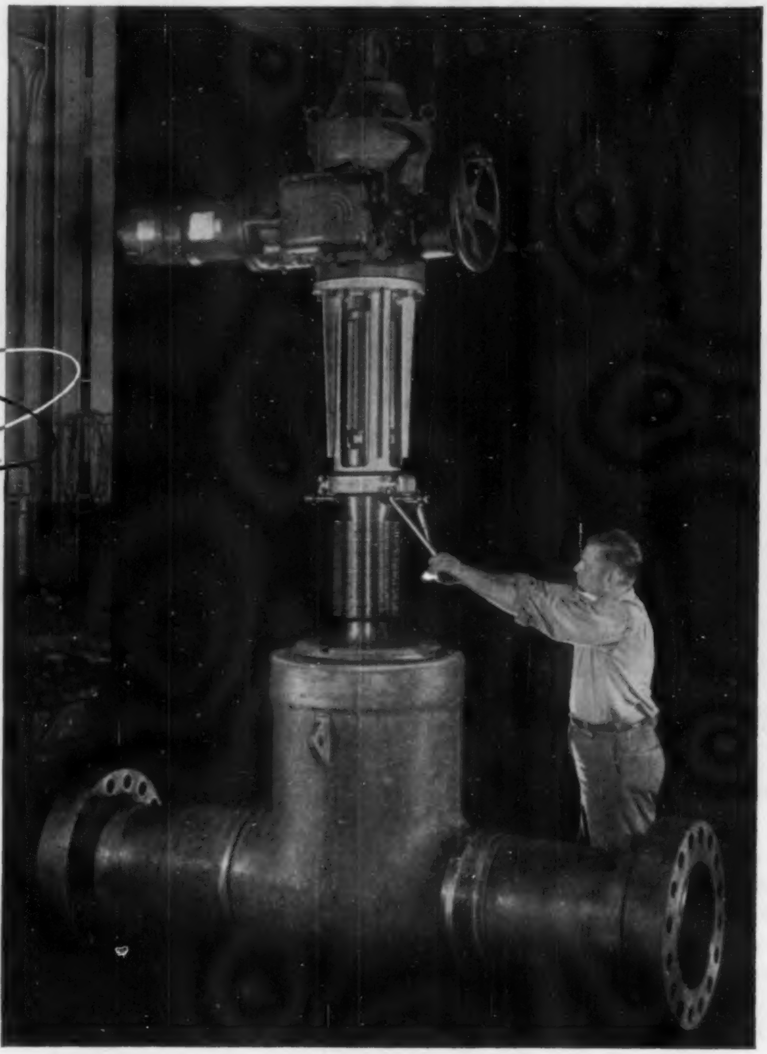

Eight Crane all-stainless parallel disc gate valves—similar to this one, but with butt-welding ends—will be on main coolant lines in new prototype atomic power reactor plant.

AGAIN... Crane leads the way in flow control for atomic power

As the age of atomic power unfolds and expands, Crane continues to lead the way in flow control.

Crane equipment is already playing an important role in the mighty *Nautilus* and *Seawolf*—the Navy's celebrated atomic-powered submarines.

Now Crane valves are ready to make history again in the peaceful use of atomic energy—in the nation's first land-based atomic power plant.

Eight Crane stainless steel gate valves—similar to the one shown above—will be on the main coolant lines in the pressurized water reactor. Crane's broad experience in flow control for atomic power—dating from the beginning of this radically different field—assures low-cost, dependable service on this critical application.

Whether your future involves atomic energy for power or radioactive materials for processing—call on Crane for the right valves and fittings. You'll find Crane has the depth in research, engineering, and manufacturing abilities and facilities you're looking for.

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First

Research-Cottrell

"Double-Deck"

Fly Ash Precipitator

Space was a big problem in this installation at the Burlington Generating Station of Public Service Electric and Gas Company of New Jersey. Two integral combination mechanical-electrical precipitators, large enough to handle 600,000 cfm of gas from Boiler No. 7, had to be squeezed into the smallest possible ground area.

If a conventional side-by-side arrangement had been used, these two units would have required about 1,700 square feet. By "stacking" the two combination precipitators, one on top of the other, Research was able to cut this space requirement by 50% — a saving of 850 square feet.

Although this arrangement had never been attempted with Research fly ash precipitators, Research knew from their experience with more than 500 central station Cottrells that it could be done. Guaranteed for 97% collection efficiency, these Burlington Generating Station units were placed in operation in October, 1955.

Perhaps you, too, have a knotty problem that demands a more creative approach — backed up by experience with over 500 fly ash precipitators. Whether you require a straight precipitator or a combination unit, at Research-Cottrell you can be sure of the most economical solution to your problem.

Other Research-Cottrell Precipitators at Public Service Electric and Gas Company of New Jersey

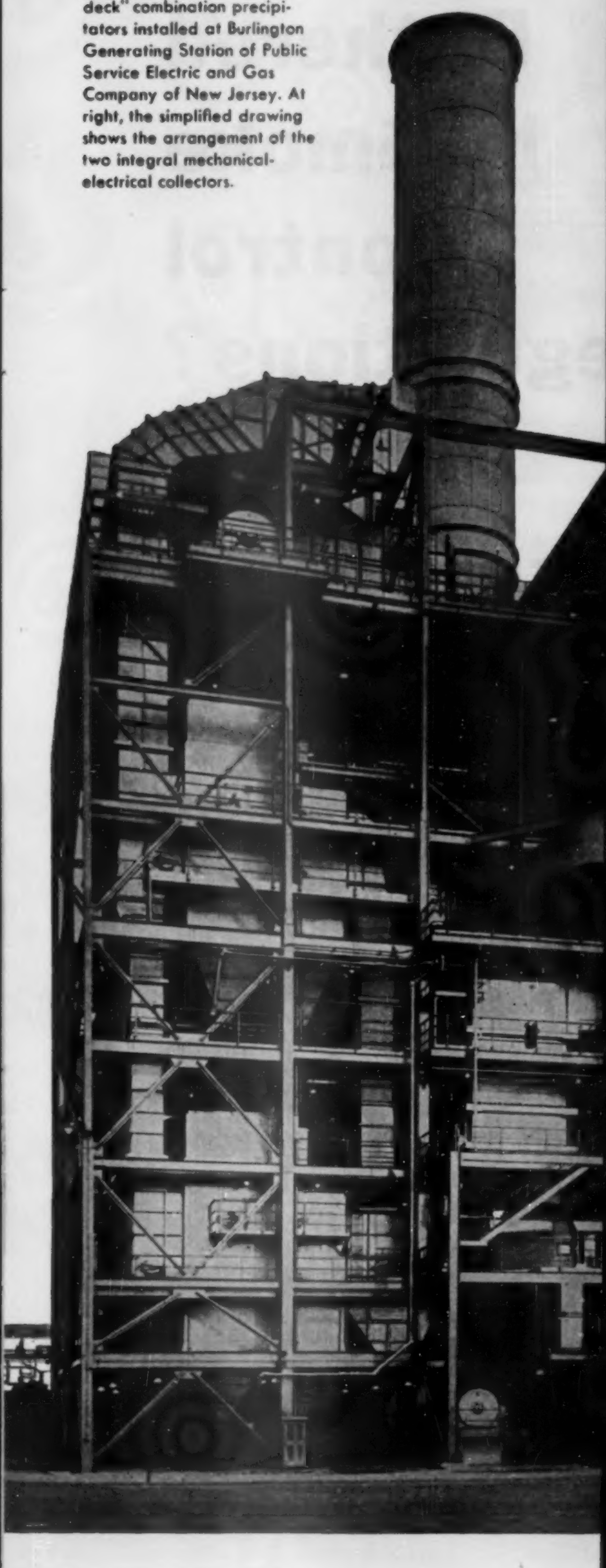
Installation Date	Generating Station	Boiler Number	Number of Pptrs.	C. F. M.
1937	Burlington	11	1	270,000
1938	Essex (Newark)	25 and 26	4	520,000
1940	Burlington	12 and 13	2	448,000
1941	Marion (Jersey City)	51 and 52	2	448,000
1942	Burlington	14 and 15	2	448,000
1946	Kearny	1 (Mercury Blr.)	1	160,000
1947	Essex (Newark)	1	3	380,000
1955	Burlington	7	2*	600,000
		Total	17	3,274,000

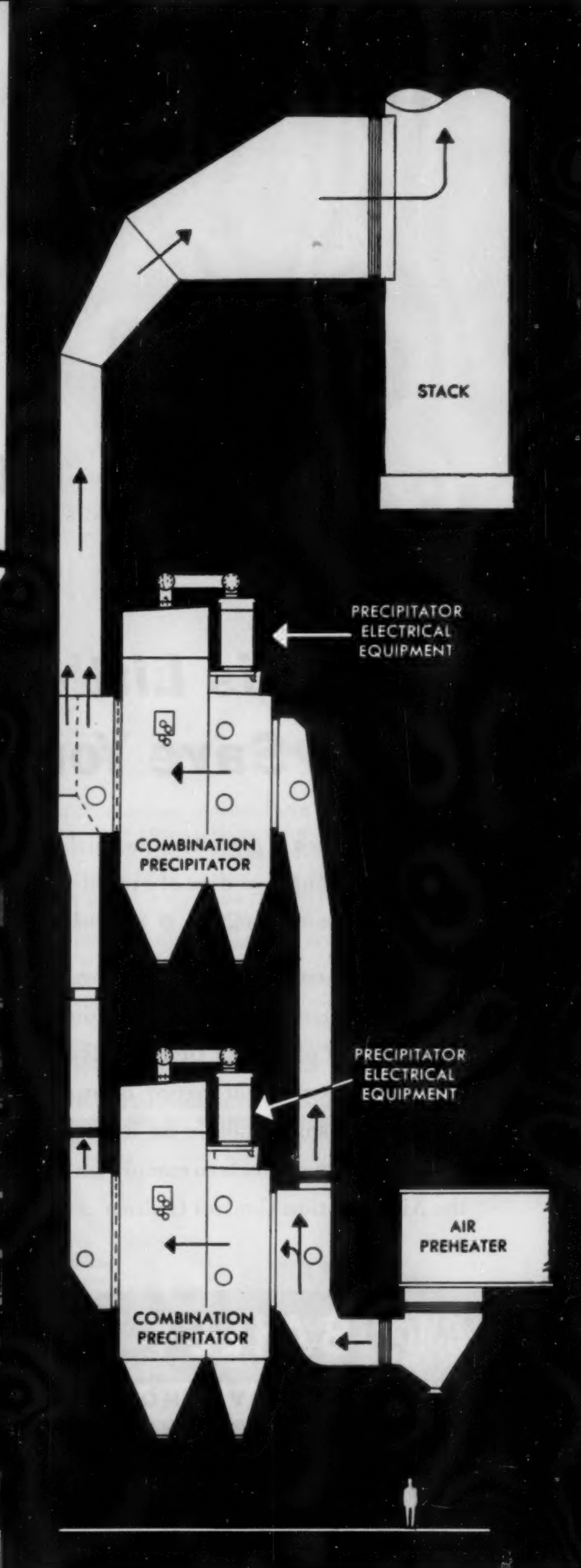
* "Double-Deck" Arrangement

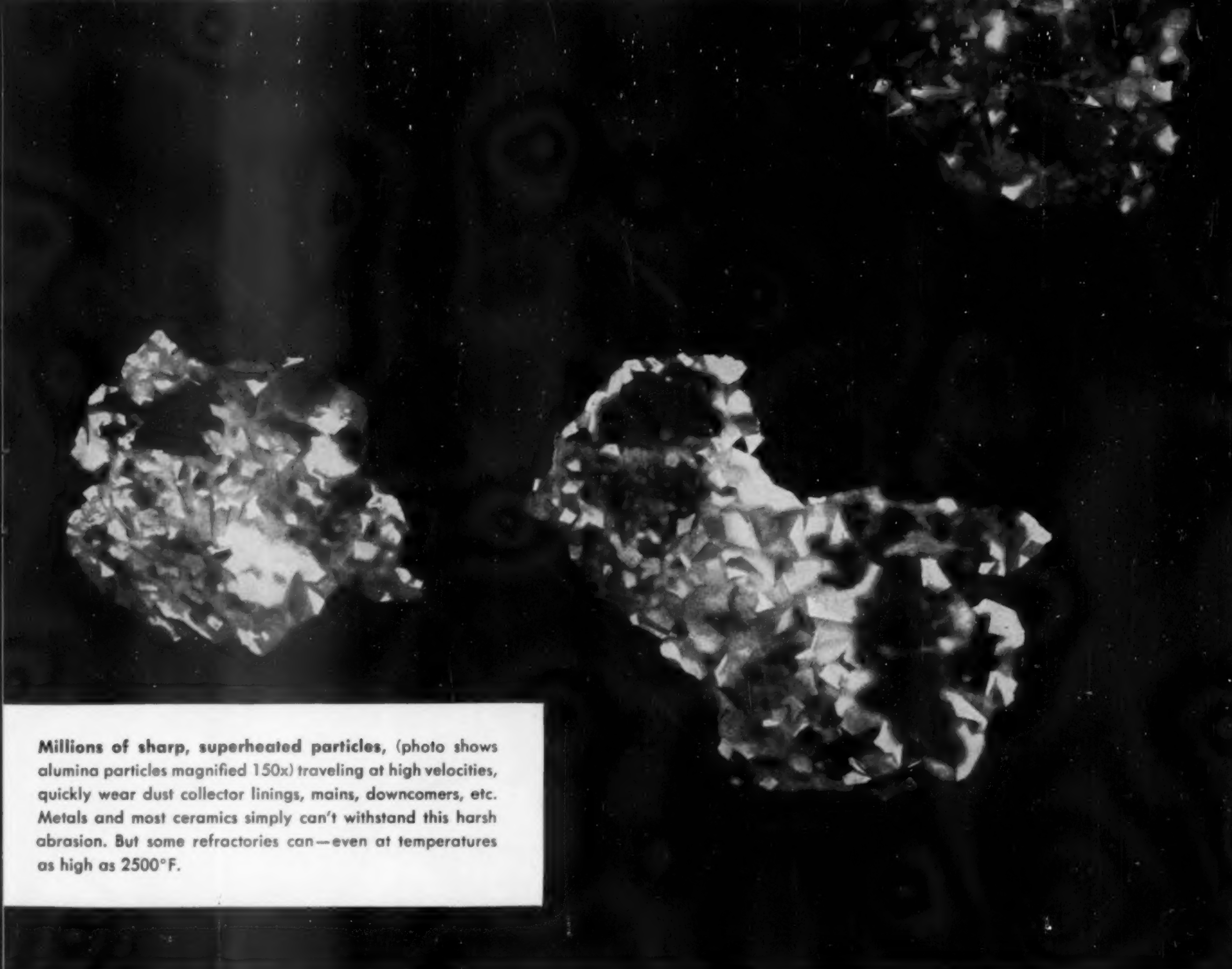
Research-Cottrell, Inc.

Main Office and Plant: Bound Brook, New Jersey • 405 Lexington Ave., New York 17, N. Y.
Grant Building, Pittsburgh 19, Penna., 228 No. La Salle St., Chicago 1, Ill. • 111 Sutter Bldg., San Francisco 4, Cal.

Research-Cottrell's "double-deck" combination precipitators installed at Burlington Generating Station of Public Service Electric and Gas Company of New Jersey. At right, the simplified drawing shows the arrangement of the two integral mechanical-electrical collectors.







Millions of sharp, superheated particles, (photo shows alumina particles magnified 150x) traveling at high velocities, quickly wear dust collector linings, mains, downcomers, etc. Metals and most ceramics simply can't withstand this harsh abrasion. But some refractories can—even at temperatures as high as 2500°F.

Refractories . . . where **abrasion** is a problem

Unequalled resistance to abrasion whether caused by tiny gas-borne particles or sliding steel billets—is one of the most useful properties of CARBOFRAX® silicon carbide refractories. For example, a CARBOFRAX dust collector lining on an ore sintering machine is still in use after 10 years service.

And when abrasion is combined with high temperature, the exceptional resistance of CARBOFRAX super refractories becomes even more apparent and useful. When used in the exhaust lines of gasoline catalytic cracking units in temperatures ranging around 1200°F, these refractories lasted 3 years, as compared to alloy rings which lasted for 6 months. On a gas fired extrusion mill furnace—where steel skids lasted 5 weeks—CARBOFRAX refractories lasted 156 weeks.

Wear resistance is not the only unusual property of these refractories. They also offer heat conductivity roughly 11 times that of fireclay, with sufficient hot strength to withstand 25 psi at 1720°C. CARBOFRAX refractories are but one of many super refractories pioneered by Carborundum and offering a wide range of unusual properties.

Carborundum's new magazine "Refractories" pinpoints many practical applications for these unusual products. The forthcoming issue carries a feature article on "Wear Resistance". Send for your copy today.

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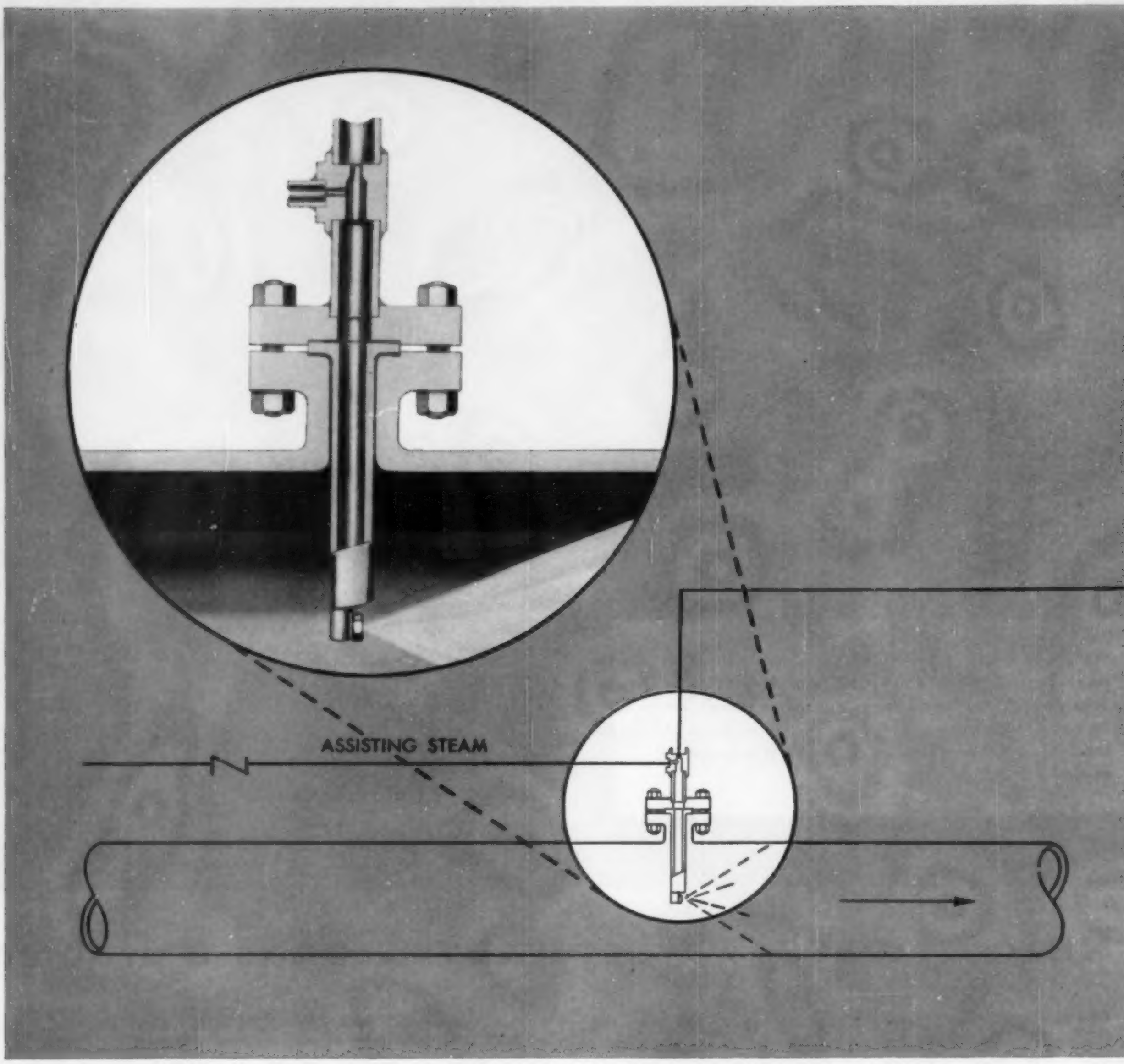
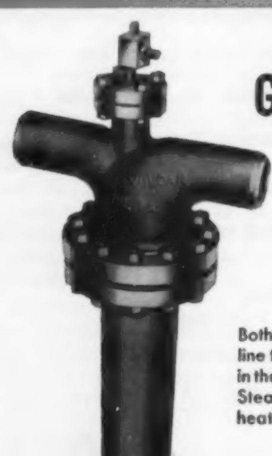




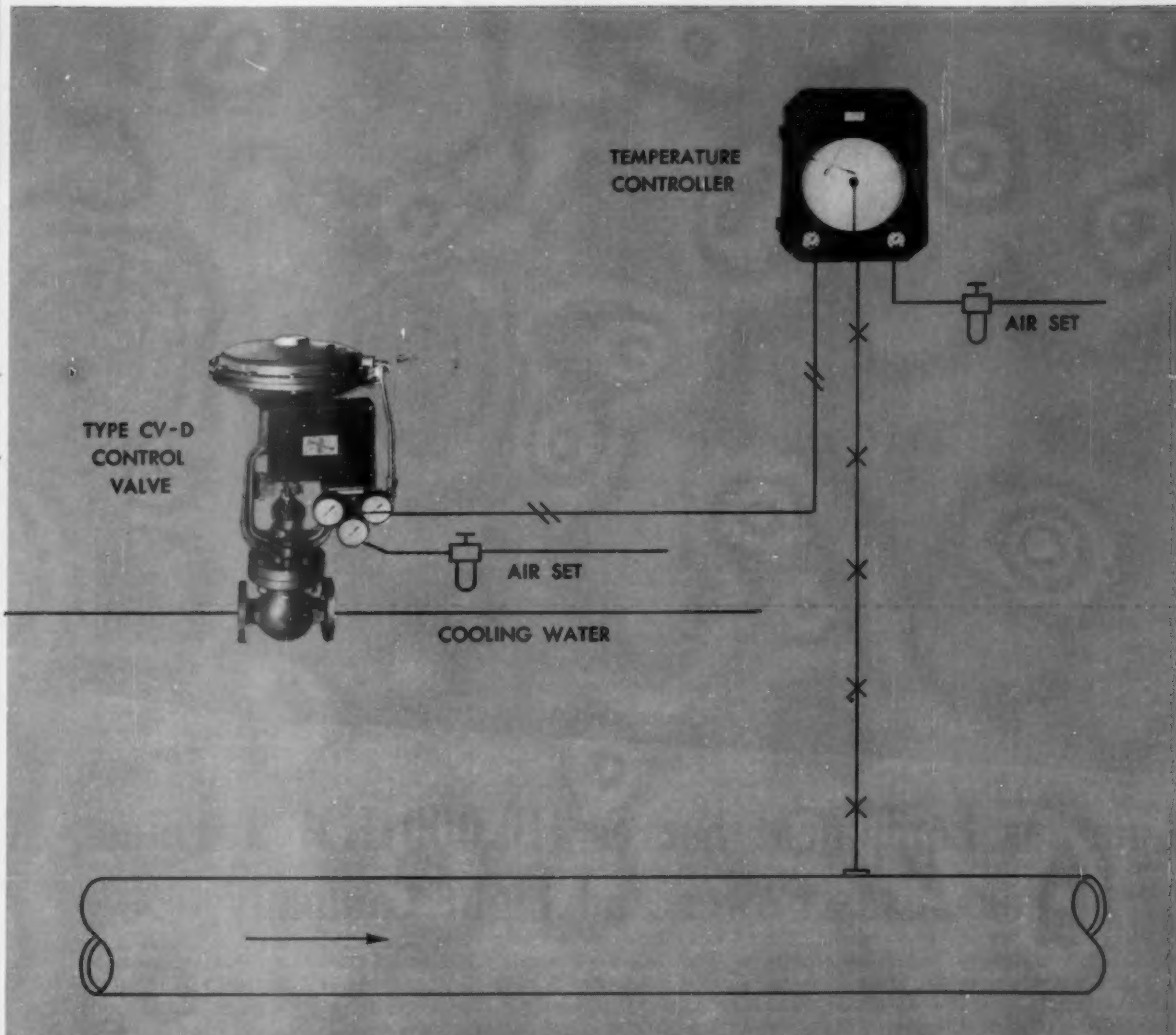
Get more accurate control with the NEW

Here is a desuperheater based on a new, proven principle that delivers more accurate control of final steam temperature for process work or auxiliaries. It uses steam only on lighter loads. As load increases, the flow of assisting steam is automatically reduced—normally without an atomizing-steam valve. Assisting steam can be off completely at high loads where no more than mechanical atomization is needed. Control is close, even at 10 degrees above saturated temperature.

Cooling water and assisting steam are intimately mixed in the exclusive Swirl Chamber—upstream from the point of injection. No large steam bubbles form to cause annoying hammer or vibration.

Incorporated into the station for close modulating control of cooling water flow is the new Copes-Vulcan Type CV-D

Both carburetor and in-line types are available in the new Copes-Vulcan Steam-Assist Desuperheater.

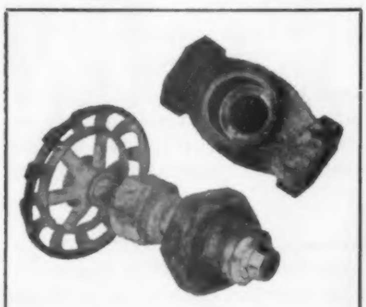


Normal installation of a Copes-Vulcan Steam-Assist Desuperheater is shown schematically

"I got 5 years of service from a valve I expected to last only 90 days"

Mr. C. L. Worthington, Chief Engineer for E. L. Bruce Co., Little Rock, Arkansas plant, standing near a Walworth No. 225P Bronze Globe Valve with "500 Brinell" stainless steel seats and discs that was installed in severe boiler blowdown service. Hardened seats and discs are especially resistant to wire drawing, steam cutting, or galling.

Some time ago Mr. C. L. Worthington, Chief Engineer for E. L. Bruce Co. plant at Little Rock, Arkansas, was having valve trouble on some newly installed boilers. The first boiler to go in service generated 600 hp operating at 200-pounds pressure. The water was so bad that a hot lime and soda ash water softener treatment had to be used, and it was necessary to add other chemicals to this solution from time to time. Mr. Worthington wanted to use a continuous blowdown to skim off the worst part of the scum on the water. He installed a small blow pipe about an inch below the normal water level in the boiler. This worked well, except that the one-inch valve on the line could only be partially opened and let a small part of the scum be blown off at one time. If the valve was widely opened, it would not take long to lower the water level in the boiler and run the steam pressure down. This service gave Mr. Worthington lots of valve trouble, as can well be imagined, because of the extreme wire drawing that occurred.



A Walworth No. 225P Bronze Globe Valve that gave perfect performance for four years and 362 days in a severe boiler blowdown service where the Chief Engineer said he had never been able to keep a valve more than 60 to 90 days.

One day the Walworth representatives in that area, called upon Mr. Worthington and demonstrated the outstanding features of the Walworth No. 225P Bronze Globe Valve. This valve, which has a working steam pressure rating of 350-pounds at 550°F, has a plug-type stainless seat and disc which has been heat treated to a minimum hardness of 500 Brinell. After listening to the Walworth men and examining a 225P valve, Mr. Worthington agreed that he would try one in the severe service described. He said if it lasted 90 days, he would consider that it had done a good job.

The valve went into service and came out within three days of being in service five years under very severe operating conditions. The valve was used 24 hours a day from early in the morning on Monday until Saturday night, when it was closed until the following Monday morning. It was never opened more than three-quarters of a turn, and most of the time it was opened only one-half to one-quarter of a turn. For the life of the valve, nearly five years, it never failed to give a 100% closure when shut on Saturday night until opened Monday morning.

When another 600 hp 200-pound pressure boiler went into service, it also was equipped with a one-inch Walworth No. 225P Bronze Globe Valve on the same service.

In view of the severe service and the wire drawing to which this valve was subjected, it is interesting to note that the original valve (which was taken out of service almost five years after it had been installed) was removed – not because the seat and disc were wire drawn – but because the turbulence of the steam had finally caused a small hole to occur in the wall of the body of the valve. Needless to say, the valve that was taken out of service was replaced immediately by another one-inch Walworth No. 225P Bronze Globe Valve, positive assurance that Mr. Worthington is satisfied that this valve has "done a good job."

Other Walworth products include complete lines of Gate, Globe, Angle, Check and Lubricated Plug Valves in bronze, iron, steel, stainless steel and special alloys. Complete information and literature will be furnished upon request.

WALWORTH

60 East 42nd Street, New York 17, New York

SUBSIDIARIES: ALLOY STEEL PRODUCTS CO. CONOFLOW CORPORATION M & H VALVE & FITTINGS CO. SOUTHWEST FABRICATING & WELDING CO., INC. WALWORTH COMPANY OF CANADA, LTD.

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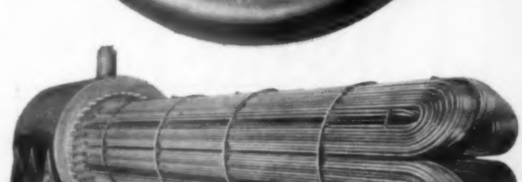

Every length of Standard Boiler and Pressure Tubing is tested at pressures far beyond code requirements and can be readily bent or otherwise fabricated.

Electric welded boiler tubing is used today by all of the leading manufacturers of boilers and superheaters—stationary, marine, and locomotive—high or low pressure—and meets the requirements of government and commercial specifications.

With recent changes in the A.S.M.E. Boiler Code, it's now possible to use electric weld boiler tubing at pressures in excess of 2,000 lbs. High strength "Grade C" tubes are available for even higher pressures.

Uniformity of temper and wall thickness makes Standard tubes easier to roll for tight . . . sure fit. Standard's fine, smooth surface eliminates any need to polish ends for tight fit. Even a microscope won't spot the exact location of the weld.

Nowhere will you find any more modern and complete facilities for precision manufacture and inspection of Boiler and Pressure Tubing than you'll find at Standard.

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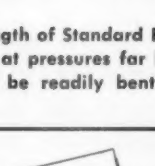

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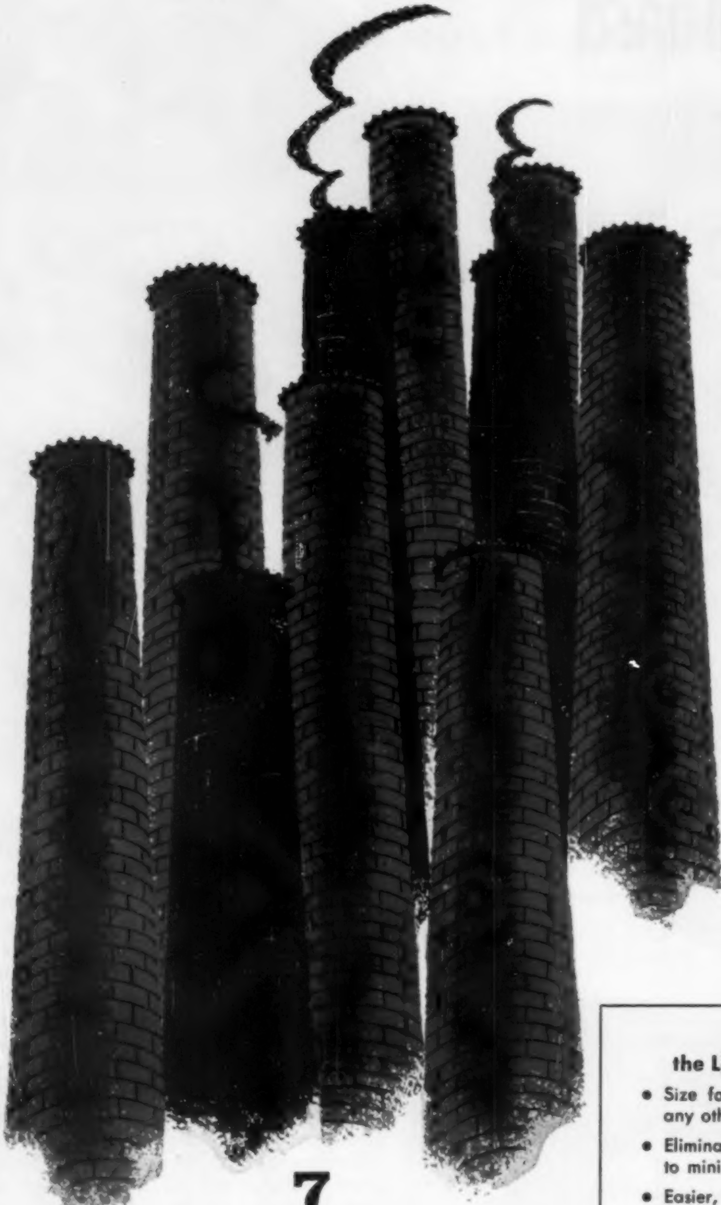
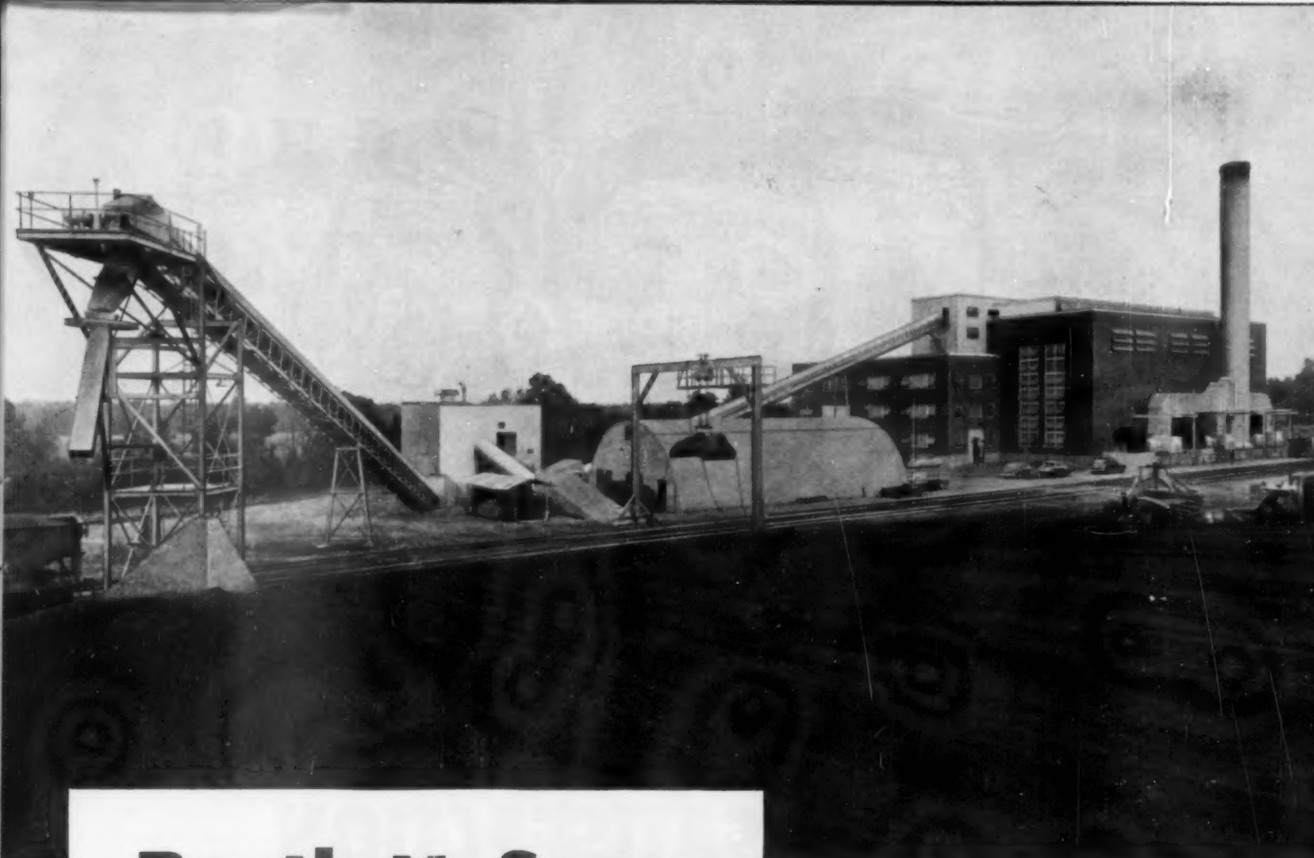
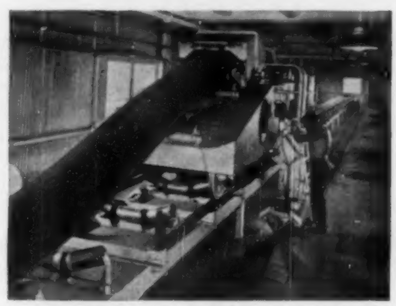




Bartlett-Snow coal handling at *Green River*

General View of Green River Power Station
Kentucky Utilities Company
Sargent & Lundy
Consulting Engineers

● The illustration above shows the first 60,000 KW unit of a plant that is to be enlarged into a 180,000 KW station. The coal handling equipment which was built, and installed, by us to Sargent & Lundy specifications, includes track hopper; duplex feeder; belt conveyors of 300 ton capacity; surge hopper for the storing out conveyor; crusher, weightometer, and sampling; inexpensive open galleries with hinged covers to protect the belt from the weather; and our newest design of motorized travelling tripper equipped to insure dust-free operation. For maximum efficiency and fixed unit responsibility, let the Bartlett-Snow coal handling engineers handle your next job.



Discharge Chutes of this Bartlett-Snow Motorized Travelling Tripper are Fitted with Plows and Rollers that Open and Replace the Bunker Seal Assuring Dust-Free Operation

View of Open Belt Conveyor Gallery. Protecting Hoods are Hinged on One Side and can be Latched in Either Open or Closed Position

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Hall Industrial Water Report

VOLUME 4 DECEMBER 1956 NUMBER 6

Water Detectives—Industry's Protection Against Loss From Boiler Outages and Costly Repairs

Sources of immediate and potential trouble are easily recognized by engineers skilled in water technology and long experienced in boiler plant operation. Hall Laboratories, Inc. has been providing this detective service for their clients for more than thirty years.

Tube Failures Caused By Low Oxygen!

On his initial visit to a plant in Northern Michigan, Hall engineer C. H. (Buck) Turner found a heavy accumulation of loose iron oxide in two 600 psig boilers.

The history of occasional failure of wall tubes due to overheating and/or thinning indicated that the iron oxide was coming from the boiler metal.

Since all evidence pointed toward an overloaded boiler, Turner recommended that steam flow studies be conducted, but these studies revealed that the boilers rarely reached their designed capacity and normally were at 75 percent or less.

Pondering this anomaly of overloaded tubes in an underloaded boiler as he approached the plant one day, Turner's attention was drawn to the plant's stacks which appeared "hot" and very dark. From experience, Turner knew this meant an extreme load or improper combustion.

Immediate questioning revealed that the carbon dioxide recorders were out of order, but spot checks had indicated carbon dioxide values in the flue gas of over 17 percent. The reported reason for this was that the economizer passes had become filled with ash and the induced draft fan could not handle the combustion gases and air required, even for a moderate load.

Turner knew that high carbon dioxide and periodic positive pressure in the furnace meant high furnace temperatures and that this could mean an overloaded furnace in an underloaded boiler.

Proof of the validity of Turner's conclusions was supplied by operating results following the cleaning of the economizer gas passage with "wet" water. No more iron oxide and a cessation of failures even in seriously thinned water walls. The title is not a misprint. The flue was the clue that low oxygen in the combustion zone had caused the tube failures.

Carryover From Faulty Steam Drum Internals

On one of his periodic service visits to a paper company plant near Pittsburgh, Hall staff engineer Doug Noll was told that a throttle valve on a variable speed steam turbine was sticking because of deposit on the valve stem.

Carryover due to unsatisfactory water conditions was not considered likely since past troubles with variable water levels and foaming had been overcome with the feed of Hagan C-1 Antifoam®. Therefore, Noll decided that the difficulty was due to something mechanically wrong in the steam drum of the boiler supplying steam to this turbine. He proved this with steam purity tests which showed 3-5 ppm of solids in the steam from this boiler and only 1 ppm of solids in the steam from another boiler.

At the first opportunity, Noll, together with the plant men, inspected the suspect boiler. They found the curtain baffle in the steam offtake drum had dropped because of loose bolts. This permitted wet steam to short-circuit from steam circulating tubes to the steam offtake. Inspection also revealed a leak in the feedwater line which could have contributed to the trouble.

The drum internals were repaired and further testing showed steam from the boiler to contain less than 1 ppm of solids. The throttle valve is again functioning properly.

Mischief Caused By Idle Boilers

The engineers in Hall's St. Louis office were really shocked one morning when they received a call from a well satisfied client of long standing complaining about the internal condition of the boilers. Hall engineer Bill Pfeiffer left immediately for the plant to see what could have happened.

Hagafilm® was being fed to prevent condensate line corrosion and the plant personnel felt that this was removing old corrosion products and returning them to the boilers where they adhered to the boiler surfaces. Not convinced that this was the case, Pfeiffer collected samples of the deposit for analysis by Hall's Pittsburgh laboratories. The analysis indicated process contamination.

Pfeiffer checked condensate from all sources but found no contamination. However, the plant operated on a five-day week and Pfeiffer suggested that condensate samples from all sources be collected again early Monday morning when the steam was first turned on.

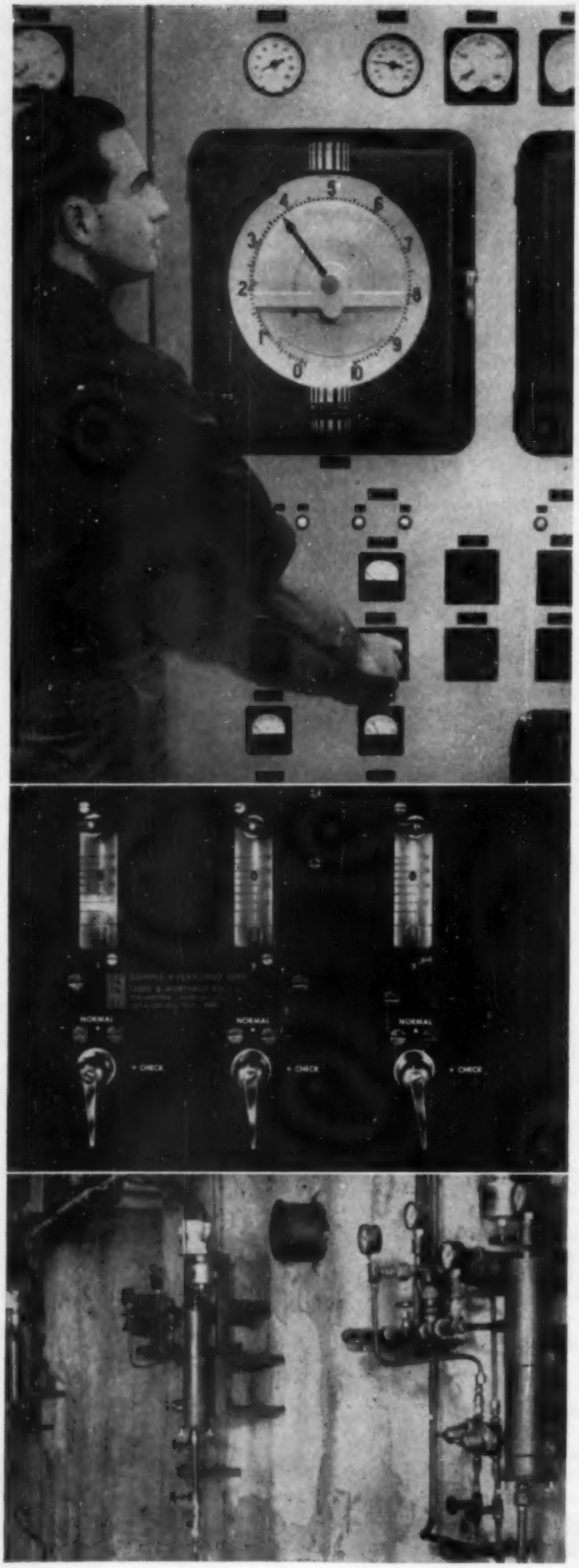
An amazing amount of emulsified oils, bonderizing solution and highly alkaline material was found in the condensate because of leakage into heating coils when the steam pressure was reduced for the week-end. Repairs were made immediately on the various coils and condensate contamination was stopped. The plant is once again enjoying trouble-free operation of the boilers.

Industrial Water Problems Require Special Handling

There are no "stock answers" to industrial water problems. For information write, wire or call Hall Laboratories, Inc., Hagan Building, Pittsburgh 30, Pa.

Water is your industry's most important raw material. Use it wisely.

Hall Laboratories, Inc.—Consultants on Procurement, Treatment, Use and Disposal of Industrial Water



THE NEW SPEEDOMAX O_2 SYSTEM GIVES A CONTINUOUSLY ACCURATE COMBUSTION PICTURE...

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Behind this operator's confidence is the new L&N Multiple-Probe Sample Averaging Unit which *assures a more representative sample.* This unit maintains a true average from two, three, or more probes—even if individual sample flows drop 60 per cent. And excess air distribution across the duct can be checked right at the Averaging Unit.

There is also a new Reverse Jet Probe and Steam Sampler which delivers a *clean pressurized sample* even with the *dirtiest* of flue gases. Water jets flush the probe passage continually, steam ejector action pressurizes the sample, and steam condensing action plus centrifugal separation remove all dirt and acid.

And, in analyzing and recording, the speed of response of the Speedomax Recorder, coupled with the efficient operation of the L&N Magnetic O_2 Analyzer, increases speed and accuracy of O_2 analysis and recording even further.

Why not learn more about this new Speedomax O_2 equipment and what it can do for you? Write to Leeds & Northrup Company, 4972 Stenton Ave., Philadelphia 44, Pa.

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Forest of Facts
on Nalco® RECIRCULATING WATER TREATMENT
NALCO Laboratories' continuous research program has gathered this forest of facts about protecting recirculating water systems. In the search for the most effective and economical formula, the metal rods shown have been rotated in all types of recirculating waters and treating chemicals. Results pointed the way to a group of Nalco Treatments which assure users against scale and corrosion in virtually any recirculating waters. For details on Nalco Treatment to fit your particular system, call your Nalco Representative, or write direct.
Test rod from water treated with the Nalco 82 Method shows protective film and freedom from any scaling or corrosive attack.
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The Nalco 82 Method is particularly suitable for scale and corrosion control in recirculating water systems which fall within the characteristic limits given here. Check them to see if your system should have Nalco 82 Treatment:
Equipment to be protected contains steel and/or brass.
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COMBUSTION

Editorial

We Say, "Amen!"

Most engineers learn to read in grade school. At the college level the vast majority of them are exposed to a course in public speaking. Why is it, then, that as they mature and become established in the engineering profession there should follow a period of oratorical retrogression? How does one explain the conduct of a chief engineer or a professor who is a recognized international authority in a certain engineering specialty and yet *reads* a paper on the same subject in a singsong manner that would scarcely earn him a passing mark in fourth grade reading?

These questions must occur to many of our readers as they attend engineering society meetings. While most societies encourage informal oral presentation, as distinguished from *reading* of papers, there are comparatively few speakers at engineering meetings who heed the suggestion. It is just this situation which prompted William H. Crew of Los Alamos Scientific Laboratory to write a letter to Dean W. L. Everitt of the University of Illinois, president of the American Society for Engineering Education. Excerpts from this letter, which appeared in the September, 1956, issue of the *Journal of Engineering Education*, follow.

"My suggestion is that members of our Society raise the scholarly tone of the programs by presenting their papers orally *without reading from a manuscript*. Quite frankly, I was aghast to note . . . the very considerable number of papers that were *read*—I mean read *word for word from copy*. This struck me as distinctly out-of-character for college teachers (of all people!). After listening to a 'read' speech, I scrambled, along with the rest of the audience, to obtain a mimeographed copy of the talk just delivered. But why?

"I think the answer is the 'read' talk fails to grip the undivided attention of the listener. It lacks vitality because it does not carry the spontaneous enthusiasm of the speaker. Therefore we pick up a copy of the speech to read on the train going home so that we can tell our colleagues what the man said.

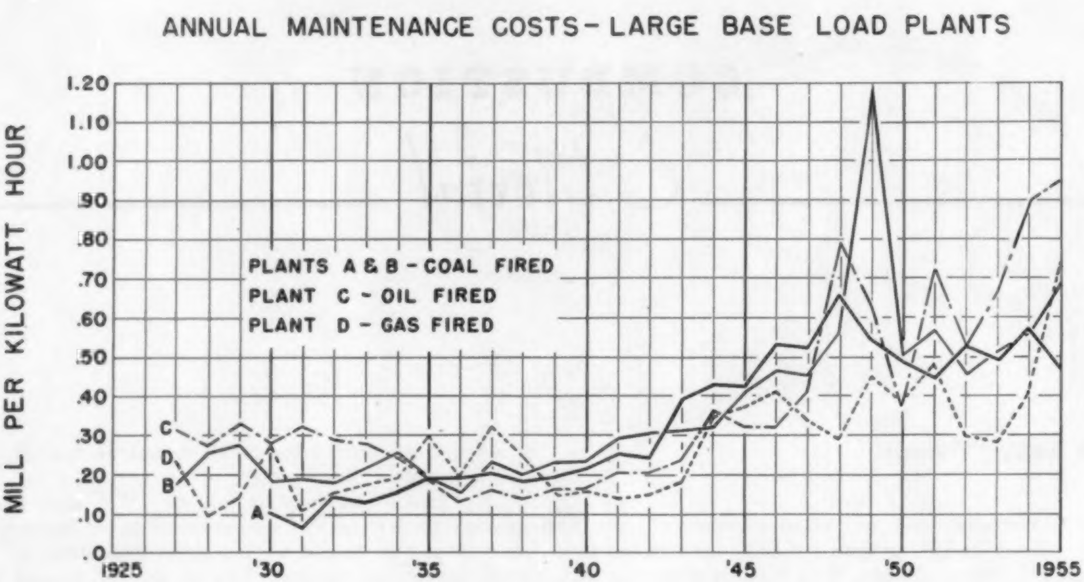
"My philosophy runs as follows. If a man has a message to deliver, the subject must be of interest to himself, and he should know a great deal about it. If these criteria are fulfilled, then let him get up and say what he has to say in the words at his command and audience interest will just naturally follow. Mind you, I think the speaker should give careful and prior consideration to the contents of his talk; and he should plan to present his ideas in an order which makes them easily understood by his audience. An inexperienced speaker feels an inward urge to write out his talk and then read it to the audience, knowing he can wrap up his thoughts in orderly, longer, and more erudite-sounding sentences. The trouble is that the more erudite the sound of a talk, the less intelligible it may be to the listener. The substance becomes confused by the form.

"I wish also to make the point that a lecture which is being prepared for publication should, in my opinion, be phrased in language which differs from that used in presenting it orally. Therefore the reading word for word from a manuscript which is to be distributed suffers from inconsistency. Either the oral presentation or the printed version is unnaturally phrased.

"Personally, I attend these meetings to see and hear *the man*. If he is going to read and distribute his talk, then I would much prefer to read it myself in the comfort of an easy chair in my own quiet and air-conditioned parlor. But if the speaker is going to talk from his heart on a subject which is dear to himself, then let me hear him under any conditions of discomfort so that I may absorb from him and share with him his enthusiasm.

"Finally, there is the man who says 'I haven't time to learn my speech; I'll just have to read it.' To this, I say, he should be mindful that perhaps the audience hasn't time to listen to what might better be read in print. Perhaps he should, if he is too busy, decline the invitation to talk."

And as our title suggests, to this we say, "Amen."



Annual maintenance costs for four relatively large base-loaded plants boasting good plant factors are portrayed in graph form for the years 1927-1955 inclusive. Each of the three principal fuels is represented in the above plot

*Steam Power Plant Maintenance Costs**

Maintenance costs and their control present a real problem to power system management. Here is an excellent study of such costs and the comparisons this study affords can help materially in expediting control of them. This paper has been prepared as a supplement to "The Cost of Steam-Electric Power" by the same author appearing in the June 1955 issue of COMBUSTION.

By H. E. ROBERTS

Cost Engineer

Bureau Of Power, Federal Power Commission

SEVERAL months ago a well-known business weekly made a very interesting statement the point of which was that "electric power men" are among the most cost-conscious in American industry. The published records of the electric utility companies for the ten-year post World War II period, 1946 through 1955, substantiates this statement. It takes "cost-conscious men" to hold down the total costs of generating and delivering electric power to the ultimate consumers during a decade in which costs, in general, have increased over 75 per cent. Combatting increased costs for labor and all materials, equipment, etc., has become a never-ending problem.

First things come first in the complex electric utility industry which means that the major cost factors of doing business receive first consideration by the management.

1. Construction costs which are capitalized and on which annual fixed charges to cover depreciation, taxes and return will run for the service life of the property. (Fixed charges will usually amount to 10–15 per cent per year on the investment.)
2. The labor component of annual operating expenses.
3. Fuel costs.

These major cost classifications are kept under constant surveillance and study. Prudent management does not overlook the possibilities of potential savings in any division of operations, i.e., production, transmission or distribution. Minor cost factors receive attention as well as the major cost components.

Today more and more attention is being given by top management, as well as those directly responsible, to maintenance costs—that is, the cost of maintaining the generating plants, transmission and distribution facilities, etc., in the proper operating condition to render good service at all times. A quick run-down of the income statement included in an electric utility's annual stockholder's report usually shows "maintenance" as a separate expense item. It is a quite sizable expense item. If the "fuel"

* The Federal Power Commission, as a matter of policy, disclaims responsibility for any private publication of any of its employees. The views expressed herein are those of the author and do not necessarily reflect the views of the Commission.

TABLE I—STEAM-ELECTRIC POWER PRODUCTION EXPENSES

(Class A and B Privately-owned Utilities)

Mills per Kilowatthour—Net Generation

	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955
(1) Operation ('Ex Fuel)	0.71	0.70	0.71	0.77	0.71	0.68	0.68	0.66	0.66	0.59
(2) Maintenance	0.58	0.59	0.60	0.63	0.56	0.53	0.53	0.50	0.51	0.45
(3) Subtotal	1.29	1.29	1.31	1.40	1.27	1.21	1.21	1.16	1.17	1.04
(4) Fuel	3.09	3.58	4.16	3.71	3.47	3.39	3.36	3.31	3.04	2.96
(5) Total	4.38	4.87	5.47	5.11	4.74	4.60	4.57	4.47	4.21	4.00
Capacity—Million Kw (nameplate 1/1 & 12/31 Avg.)	30.0	31.8	34.1	38.1	42.6	48.2	51.7	56.8	64.0	71.5
Annual Plant Factor (approximate)	51%	59%	61%	56%	58%	59%	59%	60%	57%	58%
Maintenance—% of (3)	45%	46%	46%	45%	44%	44%	44%	43%	44%	43%
Indices										
Average Hourly Earnings Elec. Lt. & Pr. Utilities (BLS)	\$1.26	\$1.37	\$1.46	\$1.56	\$1.63	\$1.74	\$1.84	\$1.97	\$2.05	\$2.14
Finished Steel Price Index —'47/'49 = 100 (BLS)	78.9	89.1	101.3	109.7	115.2	124.5	127.2	136.9	142.8	147.5

costs are given as a separate item, instead of being included in the total "operation expenses," then "maintenance" appears more significant. A further breakdown of "maintenance" between production, transmission and distribution functions, which is to be found in the more detailed annual reports made to the various regulatory authorities, indicates that a goodly segment of the total maintenance dollar goes to the steam-electric power plants.

Need for Cost Comparisons

In the January 23, 1956 issue of *Electrical World*, it was estimated that the electric utilities would spend \$597 million for maintenance during 1956 and further that 39 cents of the average maintenance dollar or \$233 million would be spent in the steam-electric and the hydroelectric generating plants. Most of this will be spent in the steam-electric, not the hydroelectric plants.

Since this undertaking is directed to the subject it is not amiss to begin by mentioning the old and still respected rule of the thumb method for estimating steam power plant maintenance costs in cost analyses which was to allow 2 per cent per year of the plant investment. In other words with a useful service life of thirty-five years the total life-time maintenance costs would be equivalent to 70 per cent of the investment. Maintenance costs take on added significance when considered in this light.

One of management's better tools is the cost comparison. How do our costs compare with the like costs for generally similar companies? What do internal cost comparisons reveal? Cost comparisons are ordinarily expressed in some convenient and easily understandable statistical form. However, statistical averages can often be somewhat misleading, are easily misunderstood and worst of all they can be extremely dull and most boring to the reader.

The risk of boring the reader will be taken with the hopes that he may find something of interest, perhaps something worthwhile in a general statistical summary of steam power plant maintenance costs based on the postwar experience. At least the writer will probably find a bit of consolation in knowing that some power production managers and plant superintendents will make a hurried inspection of the statistics to see if their own costs are above or below the averages and even perhaps to see if their system or an individual plant can be identified in any of the tabulations. Engineers are just that curious!

Maintenance Cost Comparisons

A good starting point in such a statistical review is the nation-wide results for the ten-year period. Table I presents such a condensed summary of total production expenses for the privately owned class A and B utilities based on data taken from the Federal Power Comission's annual publication "Statistics of Electric Utilities in the United States (Privately Owned)." This table requires little explanation. The unit cost per net kilowatt hour basis is used in this and the following tables as being the most logical and useful form of presentation. Included in the total capacity are all plants, large and small, old and new, owned and operated by the companies representing well over 95 per cent of the privately owned segment of the industry. Here is the overall broad picture for a decade in which the capacity more than doubled and the total generation increased over 260 per cent. The maintenance factor is presented in its proper perspective. Approximately forty-four per cent of each production expense dollar, exclusive of fuel costs is spent on keeping the plants in the required operating condition.

At the bottom of Table I are two sets of commonly used cost indices, one for electric utility labor and one for finished steel, a major material required for plant maintenance. With only small differences in annual plant factors the annual maintenance unit costs are down slightly during a period in which labor costs increased 70 per cent and steel almost 90 per cent.

Table II is a tabulation of maintenance unit costs for forty selected power pools and interconnected, integrated systems, all of which appear in Table I, for the years 1954 and 1955. These forty include over 94 per cent of the total capacity in Table I. Unfortunately the data were not readily available for the earlier postwar years for this group. All plants of the companies in the group are included. Total maintenance expenses are shown in accordance with the three principal functional subaccounts, i.e., power plant structures, boiler plant equipment and turbine-generator and electric equipment. Supervision and engineering expenses have been allocated on the basis of dollars expended for each function.

TABLE II—TOTAL ANNUAL MAINTENANCE COSTS FORTY SELECTED POWER POOLS AND INTERCONNECTED SYSTEMS

	1954		1955	
Subaccount	Thousand Dollars	Mills —Net Kwh	Thousand Dollars	Mills —Net Kwh
Structures	$ 14,080	0.051	$ 15,212	0.050
Boiler Plant	69,249	0.254	73,733	0.244
Turbine-generator & Elec. Plant	40,066	0.147	39,868	0.132
Totals	$123,395	0.452	$128,813	0.426
Capacity—Million KW (name-plate)	56.3		60.3	
Total Plant Investment (Gross), Billions	$7.1		$7.8	
Annual Maintenance, % of Investment	1.74%		1.65%	
Percentage of Total Maintenance				
Structures	11%		12%	
Boiler Plant	56%		57%	
T-G and Elec. Plant	33%		31%	

As would be expected and as generally known by power plant management the greater part of annual expenditures goes to the maintenance of the steam-generator and its associated auxiliaries, fuel handling and preparation equipment, draft, feed water and piping systems.

The unit cost per kilowatt hour is lower for this selected but representative group. The ratio of gas and oil-burning plants to coal-fired plants is about the same as in Table I. The old time 2 per cent rule of thumb basis for estimating annual maintenance costs is not too badly disrupted with the actual experience of 1.74 per cent and 1.65 per cent for 1954 and 1955, respectively.

Effect of Fuels on Maintenance Costs

Table III is presented with the idea of showing the differences in annual maintenance costs for power pools using each of the principal fuels, coal, gas and oil; also systems burning two of these fuels on a large scale. Ten large pools have been selected for which data were readily available for an eight year period 1948 to 1955 inclusive. All are included in Table II.

The steam-generating capacity of these ten pools or systems increased about 100 per cent during the eight-year period with most of this new capacity being in large, efficient, high pressure, high-temperature units. The majority of these systems also have some hydroelectric capacity, the availability of which has some effect on the steam costs. However, throughout the eight-year period the hydro capacity has continued to be a smaller and smaller percentage of total system capacity.

Over 65 per cent of the total steam power generation in the past few years was produced from coal and it is a reasonable assumption that in each year of the foreseeable future the use of coal will increase. The number of very large plants now being built and planned for the near future at mine-mouth sites or near large coal deposits cannot be taken too lightly.

The fuel burned is one of more important factors influencing plant maintenance costs as well as plant investment. Coal handling and preparation equipment require a high degree of continuous care and the never ending replacement of parts which are usually charged to the maintenance account rather than to the plant investment account. The straight gas-fired plant, with no provisions for coal, would be expected to have lower

TABLE IV—TOTAL ANNUAL MAINTENANCE COSTS PLANTS LISTED IN EIGHT ANNUAL SUPPLEMENTS, 1948–1955*

Year	No. of Plants	Capacity-Million Kw	Net Generation—Billion Kwh	Maintenance Mills-Kwh
1948	219	26.3	148	0.505
1949	245	30.8	152	0.548
1950	277	34.5	184	0.449
1951	305	40.1	215	0.462
1952	331	46.1	250	0.453
1953	374	53.4	294	0.428
1954	417	64.1	324	0.433
1955	459	75.8	394	0.399

* "Steam-Electric Plant Construction Costs and Annual Production Expenses."

boiler plant maintenance costs. Table III bears this out and shows some other interesting results.

Each of the three tables included all of the plants in a selected category. Table IV gives the average annual costs for the plants reported in the eight annual supplements, 1948 to 1955 inclusive, to the Federal Power Commission's publication "Steam-Electric Plant Construction Costs and Annual Production Expenses—1938 to 1947." These annual supplements report the more important base-load plants in the many service areas, large and small, throughout the United States. Stand-by plants as well as by-product (processing steam, etc.) plants were purposely omitted in the inauguration of this series of reports. Incidentally this tabulation includes several publicly owned plants, i.e., municipal, REA co-operatives, and TVA, that were not included in the preceding tables.

It will be noted that the yearly average unit cost is slightly lower than the corresponding costs for all plants given in Tables I and II. This is to be expected. Again it is observed that, despite the increasing labor and material costs, the unit cost per kwh is decreasing quite substantially.

Determining Good Averages

Annual maintenance costs over an extended period of years appear in Fig., p. 38, for four relatively large base-load plants which over their respective lives have been operating at good plant factors. Each of the three principal fuels is represented. Individual plant maintenance costs for a single year are not necessarily representative annual costs. The longer the period of record, especially during the base-loading years, the more reliable the average costs, provided such costs are adjusted in accordance with any consequential changes in the purchasing power of the dollar during the period.

Plants A and B are large, pulverized coal-burning plants located in metropolitan load centers which, since they were first placed in operation, have been base-load plants. Over a sustained period both have had outstanding heat rates. Plant A has two large units, 600 psi, 750 degree F (1929) and 1200 psi, 825 degree F (1938). A third, large, high-pressure unit was added in late 1955. Over the twenty-six year period this plant has averaged a 67 per cent annual plant factor. During the 10 years, 1946 to 1955, the total maintenance expense was charged 12 per cent to Structures, 62 per cent to Boiler Plant and 26 per cent to Generating and Electric Plant. The Boiler Plant expense was divided, 41 per cent to coal

storage, handling and weighting equipment, 24 per cent to furnaces and boilers, 30 per cent to boiler apparatus and 5 per cent to the steam piping system. The breakdown of Generating and Electric Plant was 42 per cent to turbine-generators and auxiliaries, 28 per cent to accessory electric equipment and 30 per cent to miscellaneous power plant equipment.

Plant B with four units (three 375 psi, 700/850 degree F and one 1250 psi, 950 degree F) has operated at a very good average annual plant factor of 62 per cent over a twenty-nine year period.

Plant C is a much smaller three-unit oil-burning plant (three 400 psi, 720 degree F and one 850 psi, 900 degree F units) located in a high fuel cost area. A 49 per cent

TABLE III—ANNUAL MAINTENANCE COSTS—TEN POWER POOLS—1948 to 1955

Pool No.	Capacity, Megawatts	Approximate Plant Factor, %	Fuel	Total Maintenance, Mills per Net Kwh: Structures	Boiler Plant	TG. & Elec. Plant	Total	Maintenance—% of Oper., & Maint. ('Excl. Fuel)
				1948				
1	978	62	Coal	0.02	0.34	0.09	0.45	47
2	1924	71	"	0.02	0.20	0.07	0.38	51
3	602	66	"	0.02	0.19	0.05	0.26	41
4	752	63	Coal-gas	0.05	0.50	0.16	0.71	49
5	927	56	Coal-oil	0.10	0.59	0.35	1.04	46
6	805	70	Coal-gas	0.03	0.16	0.09	0.28	35
7	533	59	Oil	0.06	0.26	0.25	0.57	49
8	474	70	Gas	0.10	0.16	0.18	0.44	49
9	441	79	Gas	0.09	0.14	0.18	0.41	42
10	718	60	Gas-oil	0.06	0.35	0.40	0.81	64
				1949				
1	978	55	Coal	0.03	0.36	0.10	0.49	45
2	2017	62	"	0.03	0.34	0.09	0.46	52
3	839	52	"	0.03	0.21	0.07	0.31	44
4	760	59	Coal-gas	0.07	0.47	0.24	0.78	49
5	1064	49	Coal-oil	0.11	0.50	0.34	0.95	47
6	985	56	Coal-gas	0.05	0.25	0.10	0.40	42
7	579	58	Oil	0.06	0.27	0.26	0.59	49
8	580	71	Gas	0.12	0.17	0.19	0.48	55
9	613	63	Gas	0.10	0.15	0.22	0.47	44
10	871	56	Gas-oil	0.12	0.33	0.39	0.84	66
				1950				
1	978	64	Coal	0.03	0.35	0.10	0.48	45
2	2277	69	"	0.03	0.28	0.10	0.41	52
3	885	56	"	0.05	0.21	0.07	0.33	46
4	931	47	Coal-gas	0.07	0.42	0.24	0.73	50
5	1061	54	Coal-oil	0.10	0.50	0.28	0.88	47
6	1185	71	Coal-gas	0.02	0.12	0.08	0.22	35
7	655	53	Oil	0.05	0.26	0.23	0.54	46
8	700	73	Gas	0.05	0.13	0.15	0.33	46
9	748	47	Gas	0.11	0.14	0.21	0.46	40
10	921	55	Gas-oil	0.05	0.38	0.17	0.60	60
				1951				
1	1217	65	Coal	0.03	0.33	0.09	0.45	45
2	2555	73	"	0.03	0.28	0.10	0.41	52
3	885	59	"	0.03	0.28	0.06	0.37	48
4	931	49	Coal-gas	0.06	0.40	0.26	0.72	47
5	1083	53	Coal-oil	0.13	0.50	0.32	0.95	48
6	1360	82	Coal-gas	0.02	0.12	0.07	0.21	35
7	723	64	Oil	0.05	0.27	0.26	0.58	48
8	1075	68	Gas	0.04	0.09	0.13	0.26	41
9	809	66	Gas	0.08	0.12	0.12	0.32	38
10	921	71	Gas-oil	0.03	0.14	0.10	0.27	42
				1952				
1	1378	60	Coal	0.04	0.34	0.11	0.49	46
2	2814	74	"	0.03	0.26	0.10	0.39	53
3	1053	53	"	0.03	0.22	0.07	0.32	43
4	928	61	Coal-gas	0.06	0.35	0.16	0.57	44
5	1311	51	Coal-oil	0.06	0.45	0.29	0.80	43
6	1693	72	Coal-gas	0.02	0.10	0.06	0.18	30
7	827	63	Oil	0.04	0.23	0.21	0.48	44
8	1083	70	Gas-oil	0.04	0.09	0.12	0.25	43
9	911	68	Gas	0.07	0.12	0.14	0.33	40
10	1032	50	Gas-oil	0.08	0.23	0.20	0.51	48
				1953				
1	1538	64	Coal	0.03	0.30	0.09	0.42	44
2	3343	70	"	0.03	0.26	0.11	0.40	53
3	1160	58	"	0.03	0.22	0.05	0.30	41
4	1038	68	Coal-gas	0.05	0.35	0.16	0.56	45
5	1311	60	Coal-oil	0.09	0.37	0.31	0.77	45
6	1747	74	Coal-gas-oil	0.02	0.11	0.08	0.21	33
7	974	63	Oil	0.05	0.18	0.23	0.46	42
8	1427	60	Gas	0.04	0.10	0.09	0.23	39
9	1041	74	Gas	0.07	0.11	0.14	0.32	41
10	1272	70	Gas-oil	0.04	0.16	0.08	0.28	43
				1954				
1	1697	54	Coal	0.03	0.32	0.12	0.47	47
2	3770	61	"	0.03	0.25	0.13	0.41	55
3	1357	50	"	0.03	0.17	0.08	0.28	40
4	1280	50	Coal-gas	0.06	0.35	0.19	0.60	47
5	1378	51	Coal-oil	0.09	0.46	0.29	0.84	43
6	2190	68	Coal-gas-oil	0.02	0.11	0.09	0.22	35
7	1111	63	Oil	0.05	0.22	0.17	0.44	41
8	1989	52	Gas	0.04	0.11	0.05	0.20	40
9	1346	56	Gas	0.08	0.12	0.20	0.40	43
10	1508	70	Gas-oil	0.03	0.14	0.11	0.28	44
				1955				
1	1615	62	Coal	0.03	0.30	0.10	0.43	48
2	3537	75	"	0.02	0.26	0.09	0.37	56
3	1397	59	"	0.03	0.17	0.06	0.26	40
4	1278	57	Coal-gas	0.07	0.38	0.26	0.71	49
5	1446	58	Coal-oil	0.09	0.37	0.24	0.70	40
6	2277	68	Coal-gas-oil	0.02	0.12	0.08	0.22	34
7	1350	58	Oil-gas	0.05	0.22	0.15	0.42	42
8	2113	50	Gas	0.04	0.08	0.11	0.23	43
9	1629	51	Gas	0.09	0.11	0.13	0.33	40
10	1719	74	Gas-oil	0.03	0.12	0.10	0.25	42

average annual plant factor has been maintained over a twenty-nine year period which is very good when consideration is given to the annual system load factors for the system in which it operated.

The fourth plant, designated as D, is a five-unit gas-fired installation, with four low-pressure and one 850 psi, 900 degrees F unit. It was designed and has been operated over an extended period as a base-load plant because of an available supply of very low cost natural gas. Over the twenty-nine years the average annual plant factor was 75 per cent, an outstanding performance.

After careful consideration of the increase in price levels over the twenty-six to twenty-nine year period and also the slightly lower annual plant factors of the later years the conclusion is that annual maintenance costs definitely tend to increase with the years of service.

It is realized in accordance with present day standards that the equipment reported on for these four plants is relatively obsolete for base-load purposes and that new, more efficient units and plants have and are replacing them on the lower bands of the load curve. New maintenance problems arise with the higher pressures and temperatures, automatic control systems, etc., and the past may not be too indicative of the future. However past experience cannot be ignored as a general guidepost to the future.

The cost summarizations given above will be found more useful if the reader reviews in his own mind some of the philosophy involved in engineering cost accounting, the methods of reporting and recording the daily, monthly and annual costs for the single plant and all of the plants under a single management and at times combining such costs for two or more companies. There is no such thing as a perfect cost accounting system and furthermore the people who do the accounting are human and subject to making errors and to having their own individual opinions relative to interpretations of accounts and to the details of the basic operating data subject to accounting procedures.

In the preparation and consolidation of the cost data for this paper it was assumed, and properly so, that all of the reporting has been on a generally broad and reasonably consistent basis. The period of review, except for the earlier years shown in Fig., p. 38, cover years in which most of the state regulatory bodies and the Federal Power Commission have prescribed the Uniform System of Accounts for electric utilities.[1] (See below.)

Establishing Uniform Cost Accounting

A word of caution regarding the use of this or any other system—as a practical matter there will always be some differences in internal accounting procedures between companies and within one organization. Considerable latitude is inherent in any uniform cost accounting system and interpretations on border line cases will vary. This is particularly so when it concerns maintenance expense versus capital charges (investment) and operation expense versus maintenance expense. The engineer often has some difficulty in understanding the reasoning involved in charging the cost of a major periodic boiler or turbine-generator overhaul job to annual maintenance expenses on the one hand whereas the replacement of a boiler feed pump or a circulating water pump ordinarily calls for the retirement of the old pump from plant investment and capitalizing the cost of the new equipment. This is especially true when the cost of the overhauling job amounts to ten or fifteen times the cost of the replacement. This involves an understanding of "units of property." Another troublesome problem often arises in the proper allocation of the time of operating personnel actually spent on maintenance activities. The perfect time-accounting system has yet to be devised and operated. Furthermore, the refinements of accounting can be followed beyond the point of practicality. There are other minor problems and differences, too numerous to mention. It is the writer's opinion, however, that the overall results in most instances reflect a generally consistent pattern of recording and reporting the maintenance expenditures.

Industry Awareness

Many excellent papers have been delivered at recent engineering conferences and conventions and articles are appearing in the technical power publications on the subject in general, as well as some relating to specific phases or problems. These are indicative of the study and concern now being given to the present and estimated future costs of sound power plant maintenance programs. As is frequently pointed out it is not only the actual annual maintenance costs incurred for the modern base-load plant that are to be considered. The higher fuel costs of the older, less efficient plants which are of necessity put into service to meet loads when the modern, efficient plant or unit, for that matter, is out of service must always be remembered. There will be unscheduled outages. Sound maintenance policies will tend to minimize such outages however, and at the same time will help to reduce average annual maintenance costs.

Conclusion

Electric system operations are now on such a large and complicated scale that no longer can one person, or group for that matter, keep their fingers on the numerous pertinent details that have a direct bearing on the cost of maintenance and ultimately the total cost of power production. Engineers are learning more and more each year of the necessity of having an internal cost accounting system that will keep them adequately informed on the true costs of plant maintenance. Finally, a free interchange of useful maintenance cost data between utilities is an important factor because it forms the basis for comparative cost analyses from which much can be learned and applied in a helpful constructive manner. It is the writer's impression that considerable progress has and is being made in this respect.

FPC UNIFORM SYSTEM OF ACCOUNTS

[1] The Electric Operating Expense caption of the Uniform System of Accounts for Electric Utilities divides Production Expenses, Electric Generation-Steam Power in two groupings—

1. Operation (which covers all operating labor, supplies, miscellaneous expenses and fuel) and
2. Maintenance with the subaccounts and divisions thereof as follows:
   - Supervision and Engineering
   - Structures and Improvements
   - Boiler Plant Equipment
     - Coal storage, handling and weighting equipment
     - Furnaces and boilers
     - Boiler apparatus
     - Steam piping and accessories
   - Generating and Electric Equipment
     - Prime movers and generators
     - Accessory electric equipment
   - Miscellaneous Power Plant Equipment

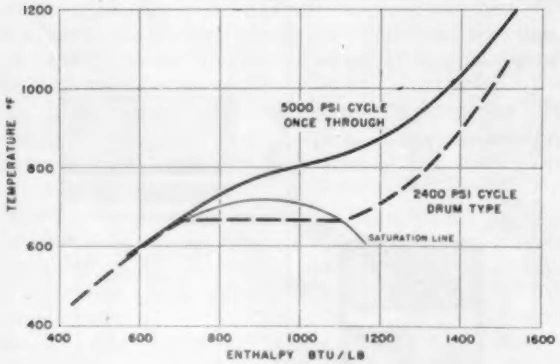


Fig. 1.—Temperature enthalpy diagram, 5000 psi cycle versus 2400 psi cycle

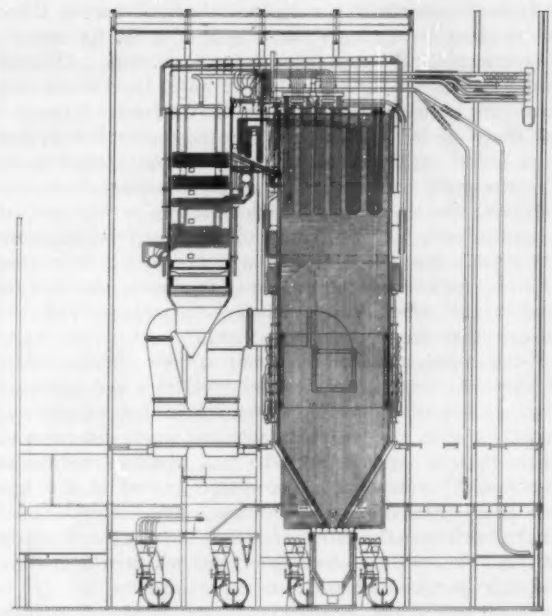


Fig. 2—Supercritical pressure steam generator—side elevation →

Engineering the Eddystone Steam Generator* for 5000 Psig, 1200 F

This paper was one of three presented before the ASME at its 1956 Annual Meeting on the design features and the engineering these features entailed in creating the Eddystone Plant of the Philadelphia Electric Co. for supercritical pressure service. The author discusses not only boiler design but also gives much detail on the boiler controls and their workings.

By E. M. Powell

Combustion Engineering, Inc.

THE steam generating unit for Eddystone No. 1 is designed to deliver steam to the turbine at a pressure of 5000 psig at a temperature of 1200 F and at a rate of 2,000,000 lb per hour. There are two stages of reheat both at 1050 F. These steam conditions make this the most advanced thermal cycle ever to be undertaken. To design such a unit required most careful evaluation of many important factors, such as the characteristics of water and steam at the extremely high pressures and temperatures, materials available for use in superheaters and piping, and the control system which would be most suitable from the standpoint of operation and at the same time afford maximum protection.

Characteristics of Water and Steam

Much has been written during the past several years, particularly, about the behavior of water at pressures above the critical point. As heat is applied at constant pressure there is a gradual increase in temperature over the entire range from feedwater temperature to the throttle temperature of 1200 F. There is no point at which the temperature will remain constant with a change of heat input. This is illustrated in Fig. 1 where temperature is plotted against enthalpy for the 5000 psi circuit corresponding to Eddystone. If this were assumed to be a continuous circuit with uniform heat transfer the curve would represent the temperature variation along its length. The corresponding temperatures for a drum type boiler operating at 2400 psi are plotted for comparison. Similarly, there will be a continuous change in specific volume as the temperature increases but there is no sudden increase in volume at a given temperature as found at pressures below the critical point. There is a range of temperatures where the fluid has the characteristics of water, while at high temperature it behaves as superheated steam. Careful study of the steam tables will show a transition zone in between which begins at about 850 F at 5000 psig.

* Presented before the ASME, Annual Meeting, November 26–30, 1956, New York, N. Y., ASME Paper No. 56-A-164.

In accordance with these physical considerations there is no point throughout the length of a heated circuit where water and steam can exist as a mixture. Designs which depend on the separation of water from steam in a drum for recirculation through the evaporative circuits are therefore not applicable. The only suitable selection is a forced-circulation design of the once-through type. For the same reason it is impossible to concentrate impurities which enter with the feedwater by partial evaporation in a boiler drum and then remove them from the system through a blowdown system. Not only does this require a revised approach to feedwater purification but it also affects the operating procedures and the design of the control system.

Once-through boilers are not a new development. There have been many designs developed and operated during the past 25 to 30 years—a few in this country but mostly within Europe. The greatest single deterrent to their general use has been the lack of adequate means for water purification. Knowledge gained in the last few years through research and experience has changed that situation to the extent that the industry is now ready to take the step to adopt principles which will achieve reliable operation at supercritical pressures.

Some years ago, in thinking ahead to the day when units designed to operate at pressures above the critical would become a reality, our management became convinced that one of the most essential items would be a control system which could be carefully integrated with the design of the steam generating equipment. An extensive series of surveys of designs operating in Europe, which took place over a period of years, indicated that the principles employed by Sulzer Brothers of Switzerland were best suited to our needs. Not only did this organization have the extensive background of experience in the successful operation of once-through steam generating units, but it also had developed a control system which could be adapted to the supercritical pressure cycle.

While there has been nothing in Europe which exactly duplicates the conditions for Eddystone, there has been considerable experience with advanced steam cycles as applied to once-through boilers. The basic principles and operating procedures are so similar as to require moderate extrapolation. The design of Eddystone then has been based on this background, plus our own experience with high-pressure controlled-circulation units utilizing small diameter tubing. In addition we have carried out a broad research program covering the problems associated with water purification and metallurgy for high-temperature, high-pressure work. This will be discussed in more detail later in the paper.

Steam Generating Unit

The design of this unit follows the general pattern of two-furnace units which we have developed for capacities of from 200 Mw and up. Insofar as possible it will be made up of standard components with which there have been many years of successful operating experience. The two notable exceptions are the once-through flow of water through the pressure parts and the design of superheater for the high steam temperature with high pressure.

This unit, shown in Fig. 2, consists of two identical furnaces of dry bottom type, each fired with tangential burners located in the four corners. Since there are two reheaters in this cycle one can be associated with each furnace. In that way each can be controlled independently by burner tilt, thereby avoiding the necessity for spray desuperheating. This will make it possible to obtain the maximum cycle efficiency and at the same time provide constant reheat temperatures over a wide range of ratings. Steam temperature to the turbine will be regulated by proper proportioning of water flow through the heating surfaces and will be discussed more fully with the control system.

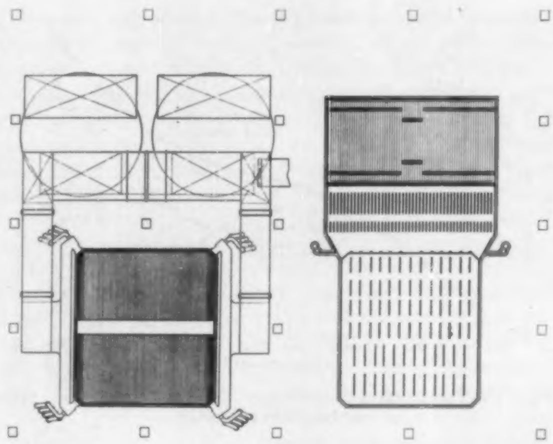


Fig. 3—Supercritical pressure steam generator—plan view

Full consideration has been given in the furnace design to past operating experience with coals which will be available to this plant. Sufficient cooling has been provided to avoid sticky ash deposits in the closely spaced convection surfaces. The walls are completely covered with tangent tubes with no exposed refractory to facilitate cleaning with wall blowers.

The heat cycle adopted for Eddystone by its nature and the amount of superheating and reheating to be done indicates the necessity for a new approach to the arrangement of heating surfaces. For example, 65 per cent of the heat absorption will take place in the superheaters and reheaters. Obviously, this indicates the desirability or necessity for greater use of radiant superheating surface than normally used with conventional designs for lower pressures and temperatures. This led to installing radiant superheaters on the upper furnace walls and the extensive use of widely spaced platens suspended in the upper portion of the furnace. Sufficient cooling surface has been provided in this manner to cool the gases to approximately 1650 F before leaving the furnace chamber at the top and entering the finishing stage of superheater.

Numerous studies were made of various arrangements of heating surface before adopting the one illustrated here. In these studies the following primary considerations were established:

1. Each of the two reheaters should be controlled independently by burner tilt to maintain 1050 F over a two to one load range.

2. The combination of radiant and convection heating surface must be such as to provide the best possible control characteristics over the expected load range.

3. At the same time consideration must be given to

affording maximum protection to the metals in the pressure parts and the high temperature superheater section, particularly under conditions which will exist during start up as well as normal full load operation.

4. Proper temperature differential between gas and steam must be established for efficient heat transfer in order to obtain the high boiler efficiency compatible with this heat cycle.

In the design which was finally adopted, the heating surface for the high pressure circuit is the same in each half of the unit. Feedwater enters the economizer and flows upward through tubes cooling the side walls of the convection pass. It is collected in a header on each side wall and directed through piping to the entrance to the tube circuits covering the lower furnace walls. These up-and-down circuits terminate in two headers located at the center of the front wall. The water which is collected at this point is then taken through piping to the convection surface at the top of the rear pass through tubing forming cooling for the front and rear walls of the convection pass. The transition from water to steam, discussed earlier, takes place in this zone of low gas temperature and reduced heat transfer. Two separate circuits have been maintained through this point for each furnace, making a total of four circuits, each with its own independent control system to maintain uniform metal temperatures and match the water flow to heat absorption as required. This will be discussed more fully later in the paper.

Each circuit is then subdivided into two through piping and then directed to the radiant superheater forming the walls of the upper third of the furnace, where it will pass through a series of horizontal tube circuits up to the roof. Final superheating is done in the platens in the upper front corner of the furnace and the convection pendant loops just beyond the furnace outlet. In this way superheating to 1200 F has been done in a zone of minimum gas temperature compatible with the steam temperature from the standpoint of heat transfer, thereby resulting in the minimum metal temperature. Heating the tubes around their entire circumference also serves to reduce the temperature stresses in the tube wall. These principles were considered most important to insure the successful operation with this advanced cycle and the new alloys which are associated with it. The division into eight individually controlled circuits was justified by the same reasoning.

There is a complete reheater associated with each of the two furnaces. Steam from the turbine enters at the rear and is heated in two stages—first by convection in the rear pass immediately above the economizer and then by radiation in the platens located at the top of the furnace. The two reheaters are substantially the same, modified slightly to suit the difference in steam temperatures from the turbine.

The plan view, Fig. 3, shows sections taken through the two furnaces, one at the elevation of the platens and the other lower in the furnace just above the burners.

The platen superheaters and reheaters are approximately 25 in. apart across the furnace width. Furnace gas will enter this surface at low velocity, about 25 fps at peak load, and leave at about 37 fps. The finishing superheater is spaced across the furnace on $9^3/_{32}$ in. centerline. All of these will be recognized as far more conservative than any unit designed to date.

There will be four Ljungstrom air heaters, two per furnace, and a symmetrical duct system so arranged that the air supply to the two furnaces may be controlled individually.

Several years ago it became standard practice to support units from overhead steel to simplify the supporting structure and eliminate expansion problems. The same principle has been followed with the design of this unit.

The drive to eliminate extraneous air leakage into the setting over the past few years, to permit efficient combustion with reduced excess air, led to the development of cubical expansion of pressure parts backed by a skin casing. The casing and tubes would expand together being the same temperature, thereby eliminating expansion joints. These principles are being followed here insofar as is possible. Of course, in the supercritical pressure cycle there is a constantly increasing tube temperature over the entire length of the circuit. This factor has required some modification to standard design details in order to achieve our overall objectives and at the same time provide for free expansion of individual tubes to allow for differential movement.

Small diameter tubes have been used for many years to line the walls with the controlled-circulation design. This led to the development of shop assembly of those tubes in large panels. Considerable savings have been effected in this way in shop handling, shipping and field erection. In order to obtain minimum tube wall thicknesses and minimum stresses consistent with the high pressures and temperatures encountered with the Eddystone cycle, one and one-half inch diameter tubes will be used throughout the high-pressure circuits. It is not considered practicable to weld tubes together continuously, as has been done with some controlled-circulation units, because of the variable temperatures involved. On the other hand, it is planned to fully exploit the advantages of preassembly in the shop. Procedures are being developed for the entire furnace lining and the pendant superheaters and reheaters as well.

Control System

The most important single function of a control system for an advanced steam cycle such as this is the regulation of steam temperature, as has been emphasized throughout this paper. Not only does this apply to the final steam temperature to the turbine but throughout the entire circuit if optimum metal temperatures are to be achieved in the pressure parts and assure a long service life.

The simplest form of once-through boiler is a single-tube circuit through which the water passes once and is superheated to the desired temperature at the outlet. Obviously, such an approach is impossible when dealing with a flow of 2,000,000 lb per hour. A multiplicity of circuits is required to achieve the desired objectives of small tube diameter and an overall pressure drop which can be economically justified. There are two basic solutions to this problem.

The first is to divide the circuit into comparatively small increments. Mixing headers can be provided at the outlet of each section and additional headers at the inlet of each succeeding section for redistribution of the water or steam to the parallel circuits. The second solution is the use of completely separate continuous circuits. Each of these could be independently controlled to proportion the water flow to the heat absorption

as it might vary from tube to tube. Such a system would require a prohibitive quantity of control equipment.

Neither solution alone was considered practicable when consideration was given to the size of unit made up of two furnaces and the non-uniformity of heat absorption that experience has shown can be anticipated with such large areas. The design chosen for Eddystone is a combination of the two systems. Four independently controlled circuits are used from the economizer inlet to the outlet of the transition section, each consisting of a number of parallel tubes. At this point each system has been divided into two circuits, each with independent controls for water injection. Headers have been provided at four intermediate points where the flow through each circuit may be thoroughly mixed before passing to the next section of heating surface. The control devices are located at these points. The combination of positive controls and mixing headers assures most uniform temperature distribution throughout the circuits.

The control system is divided into three primary functions: (1) Feedwater flow and its distribution are directly associated with steam temperature regulation. (2) The bypass system is regulated for the protection of the turbine and steam generator during starting and emergency conditions. (3) The combustion controls are interconnected to the turbine to satisfy the needs of generator output and pressure regulation.

Expressed simply, the output of a turbine-generator is a function of the heat energy in steam supplied to the turbine throttle. The quantity of heat required for a given load is regulated by the combustion control equipment. It is then the function of the feedwater regulating system to proportion the water flow to the heat fired to provide the proper steam temperature at the turbine throttle. Total heat is the product of flow rate and heat content per pound, the latter being a direct function of temperature and pressure. With this direct and simplified approach we reach the ultimate in complete integration of boiler and turbine into a true unit system.

Feedwater Regulation

The control system for feedwater regulation can be described most clearly from a simplified diagram, Fig. 4, showing a single circuit through the steam generator. The objective of this system is to regulate steam temperature at three points in the circuit: the outlet of the transition section, outlet of the radiant superheater, and outlet of the finishing superheater. While such a high degree of refinement may not be an absolute necessity, it was thought highly desirable for the steam conditions at Eddystone. The advantages anticipated are (1) a more positive control at throttle temperature minimizing fluctuations, and (2) more complete control of metal temperatures throughout the entire steam generator.

Feedwater flow to the economizer is regulated by a regulating valve at the inlet which is designed and operated in such a manner that flow is a direct function of valve position. An anticipating impulse from steam flow is provided by the pressure differential across a flow nozzle in the steam piping leaving the transition section. This will sense immediately any change in steam flow to the turbine. The final impulse comes from a thermostat at the same location correcting the feedwater flow to maintain the desired steam temperature. Maintaining this temperature matches the feedwater flow with the heat absorption in those heating surfaces.

In order to obtain the desired control characteristics of the feedwater regulating valve the pressure drop across the valve is automatically maintained constant by the pressure difference regulating valve immediately ahead of it. This compensates for variations in feed pump pressure and boiler pressure so that the feedwater quantity depends exclusively on the setting of the feedwater valve. The four pressure difference valves are interconnected with the speed regulators of both feed pump turbines to assure adequate supply for the entire unit and maintain the valve positions within the desired range.

The final steam temperature is regulated in two additional stages by means of water injection at the inlet of the radiant superheater and at the inlet of the platen section. There are in effect three-element controls. The first stage functions as follows: (1) Water is taken from the feed line between the pressure difference valve and the feedwater regulating valve. Due to the method of controlling the regulating valve, the pressure at this point is a direct function of load. For a given opening of the injection valve the quantity of water flow will be in direct proportion to the steam flow. An increase in steam flow automatically increases the quantity of injection water. (2) The thermostat at the outlet of the transition section provides an anticipating impulse to the injection valve on change of firing rate which will produce a change in steam temperature at that point. (3) Final vernier regulation of the injection valve is accomplished through the thermostat located at the radiant superheater outlet.

The second stage functions in a similar manner. In-

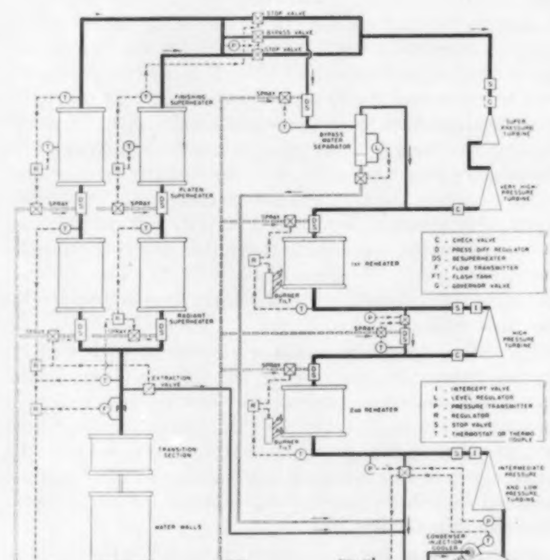


Fig. 4—Simplified flow diagram showing controls and start-up system

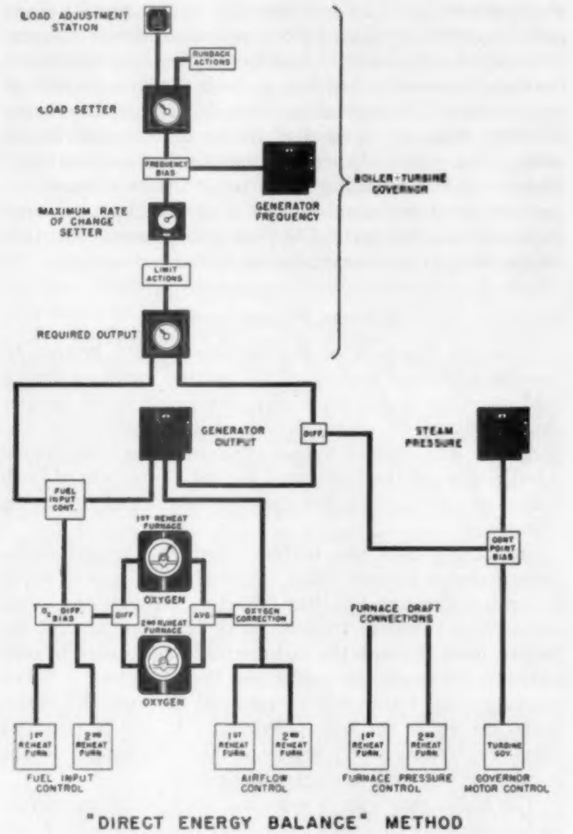


Fig. 5—Basic combustion control diagram—direct energy balance method

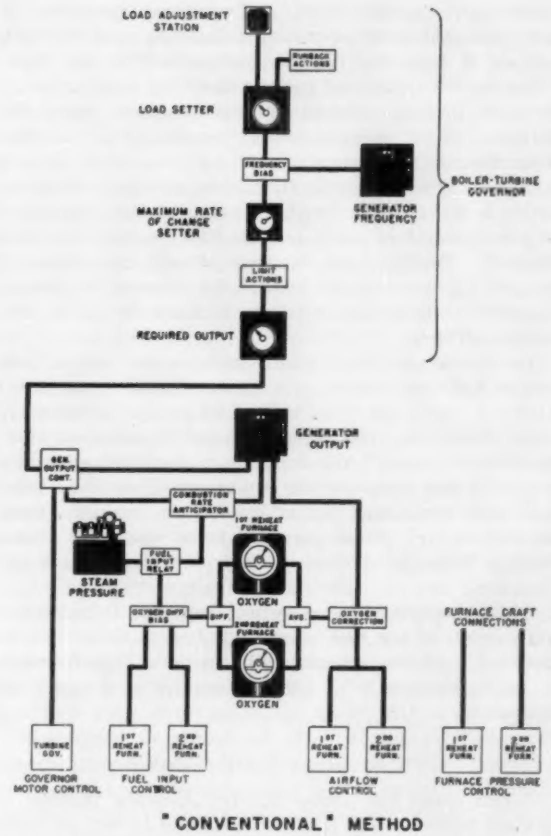


Fig. 6.—Basic combustion control diagram—conventional method

jection water is taken from the same source as for the first stage. It is injected through the valve under control of the thermostats located between loops of the platen surface and the outlet of the superheater. The locations of thermostats used for anticipation in both cases were chosen on the basis of calculations to determine optimum response characteristics.

Combustion Control System

The integrated boiler-turbine combustion control system regulates the turbine governor and the input of fuel and air supplies to the boiler to give the required generator output while maintaining a uniform steam pressure. Consideration is being given to the installation of two basic methods of control so that the operator may select either one through a transfer switch.

1. With the "Direct Energy Balance" method, the *input* of fuel and air supplies to the boiler unit is directly regulated from the unbalance between *required output* and the actual *generator output,* while the turbine governor is controlled to maintain a uniform steam pressure. With this arrangement the boiler input is directly controlled to give the desired generator output, and the turbine keeps in step with the boiler output.

2. The "Conventional" method regulates the turbine governor to give the required generator output while the boiler input is basically controlled to maintain steam pressure. Combustion rate anticipation is obtained from the generator output, plus the regulation applied to the governor motor. With this arrangement the boiler follows the turbine demand.

In the supercritical pressure cycle utilizing the once-through principle, the boiler and turbine must be closely integrated as a unit. The Direct Energy Balance method of combustion control was developed by Leeds and Northrup to accomplish this objective through a more direct-acting control system.

As a further means of better coordinating overall operation of the unit, the combustion control system employs a "boiler-turbine governor" component, which is a new concept in the control of steam-electric units. It provides a means of (1) changing boiler-turbine output in an orderly manner, and (2) keeping the output within the capabilities of the boiler and turbine. This governor component is sensitive to generator frequency, which adapts the combustion control to the normal inherent regulation of the standard governor.

The "boiler-turbine governor" integrates and supervises the operation of the boiler-turbine unit. It is composed of "load setter," "frequency," and "required load" servos. These three servos are analogous to the synchronizing motor, speed sensitive element, and turbine valve position of a standard turbine governor. It includes a rate sensitive element to limit the maximum rate at which the required output can change, thus keeping within the response characteristics of the boiler-

turbine equipment. The "boiler-turbine governor" is also provided with appropriate limiting and runback actions to keep the required output within the capabilities of the boiler and turbine auxiliary equipment.

These limiting actions in this governor block the travel of the "required output" servo. For example, when the fuel or feedwater equipment in service is at a maximum or minimum limit, further increase or decrease action is prevented. Similarly, when the fan equipment or governor valves reach an open limit, increase travel is blocked. During load changes, should the generator output lag the required output by a preset deviation, appropriate limit action occurs to keep the boiler and turbine in step.

In addition to these limits, suitable runback actions are included to reduce the required output to preset limits on loss of one set of boiler feed pumps, or one set of fans. Similarly, the panel-adjusted "maximum-minimum limit setters" also function to keep the generator output within range for the equipment in service. Likewise high steam temperature leaving the transition zone, as well as high steam pressure, when using the Direct Energy Balance Method of control, will run back the "required output" servo accordingly.

This "boiler-turbine governor" system is employed with either of the two aforementioned methods of control and is shown schematically on both Figs. 5 and 6. A brief description of the two methods of operation follows.

Direct Energy Balance Method

When using the Direct Energy Balance method of control, as shown on Fig. 5, the fuel input to both furnaces is controlled to maintain a balance between *required output* and *generator output*. The fuel supplies to the two furnaces are automatically biased from *oxygen difference* to compensate for differences in fuel quality and feeding conditions between the two furnaces.

Air flow through each furnace is initially balanced against generator output, and this relationship is automatically compensated from the average oxygen content of the flue gases in both furnaces as required to maintain a uniform combustion efficiency. Each furnace air flow controller regulates its respective pair of forced draft fan inlet vanes, while a furnace pressure controller at each furnace adjusts its respective induced draft fan dampers to maintain uniform furnace drafts.

The standard turbine governor motor receives its regulation from a steam pressure controller, the control point of which is automatically biased during load changes to provide maximum response of the boiler-turbine unit.

Conventional Method

The Conventional method of operation is shown schematically in Fig. 6. With this arrangement the standard turbine governor motor is controlled to maintain a balance between *generator output* and *required output*.

Fuel input to both furnaces receives its initial regulation from changes in *generator output* plus the regulating impulses applied to the standard governor motor, as introduced through the "combustion rate anticipator" unit. This initial control action is modified as required from the steam pressure controller to maintain a uniform steam pressure. The fuel supplies to the two furnaces are automatically biased from *oxygen difference* to compensate for differences in fuel quality or feed conditions between furnaces. Air flow to each furnace, as well as furnace draft, is controlled the same as for the Direct Energy Balance method. With both methods of operation a panel-adjusted "minimum fuel and air flow" setter prevents reducing boiler input below a preset adjustable limit on complete loss of system load. Under this condition the turbine bypass system would function as required to accommodate the boiler output.

Turbine Bypass System

It is the function of the turbine bypass system to provide adequate cooling of all heating surfaces during cold starting and permit the development of proper characteristics of steam before it is admitted to the turbine. The turbine bypass system will be used during a hot restart of the boiler and for the protection of both boiler and turbine in the event of abnormal operating situations.

Steam bypasses the turbine through the automatic superpressure bypass valve, through the bypass water separator, through the first reheater, through the automatic high-pressure bypass valve and the second reheater, then through the automatic low-pressure bypass valve to the condenser cooler and the condenser. When starting cold, water will be pumped through the entire boiler circuit to the bypass system. It will be removed from the bypass water separator and discharged to the condenser hot well through a flash tank.

The boiler stop valves will close from low-temperature or low-pressure impulses to prevent the admission of wet steam or water to the turbine. In addition to assisting with starting, the superpressure bypass valves serve as relief from over-pressure or over-temperature. The high-pressure and low-pressure bypass valves are automatically operated, as well, to limit the pressure levels maintained in the bypass system as desired.

Three automatic water injection valves are provided to protect materials against over-temperature when the high temperature steam is discharged into the system. The first is located at the outlet of the superpressure bypass valve to limit the steam temperature entering the separator and first reheater to that which would normally exist in the cold reheat line at full load. The second is located beyond the high-pressure bypass valve to limit the steam temperature to the second reheater in a similar manner. The third is associated with the condenser cooler for the protection of the condenser.

The entire turbine bypass system is designed to permit operation of the boiler at 30 per cent of its design capacity with full primary steam pressure and temperature with the turbine isolated completely. Safety valves would not function during this operation. Some heat will be recovered in feedwater heating through normal extraction lines. Thus it will be possible to match steam temperatures to those existing at the three admission points to the turbine before starting a hot machine.

Following a turbine tripout when the outage is expected to be of relatively short duration, it would be undesirable to cool the steam generating unit down and restart from a cold condition. In such a situation sufficient water will be passed through the circuits in the lower furnace for their protection in the burner zone. At the same

time the quantity allowed to pass through the high-temperature superheater tubing and main steam piping to the turbine will be reduced. This will minimize the temperature shock to that material and recover temperature more quickly. It will be accomplished by extracting steam from the circuit at the inlet to the radiant superheater as indicated on the diagram. The control valve in the extraction line will be regulated automatically by the steam temperature leaving the radiant superheater. The function of this control will be to limit the reduction of temperature at this point insofar as is possible. Obviously, it will also function as a safety device in the event of loss of fuel input.

The high-pressure system and each of the reheaters will be completely protected by safety valves with full load relieving capacities, although it is intended that the bypass system shall operate in such a way as to minimize the occasions when the safety valves must operate. Naturally, without a boiler drum it will not be possible to locate these valves strictly in accord with the existing rules of ASME Boiler Codes. Some variations will be necessary following sound engineering principles in the development of a logical and balanced design. This applies particularly to the valve location which will be at the superheater outlet, and establishing pressure levels for the selection of materials.

Research

As mentioned earlier, the successful operation of once-through boilers depends on satisfactory water conditioning. The solution of this problem has been the result of many years of research and development both here and abroad. After careful consideration of the results which have been achieved in the several programs under way, most of the fears regarding water problems in supercritical pressure boilers have gradually disappeared. Again it is the situation where dispelling the unknown gradually has led to confidence in successful operation at supercritical pressures. Most of the attention now is being directed toward determining safe limits and means for assuring that such limits are met. One of the problems in this connection is developing analytical methods of sufficient sensitivity and reliability. Concentrations to be measured accurately are very low in terms of past practice.

Solid matter in the system must be minimized to prevent objectionable deposits in the boiler and the turbine. There are four recognized sources for introduction of solid matter, the most critical of which could be condenser leakage. The extreme importance of regulating this item has been recognized; full attention is being given to insuring absolute tightness of tube joints including coating of the tube sheet with a resilient sealing material. The hot well under the condenser has been sectionalized so any localized source of contamination can be isolated. The contaminated water will then be removed from the system where it can be filtered and demineralized. A more detailed discussion is included in Mr Harlow's paper.[1]

Next to condenser leakage, metal pickup from corrosion has been considered by many to be the greatest source of solids in the water. As with today's conventional systems the preboiler system will be an important source of this material. The same causes will apply and therefore will be subject to the same curative measures Dissolved oxygen in the feedwater should be limited to 0.005 ppm and the pH controlled to 9.0 to 9.5. Eddystone is designed for deaeration of the feedwater in the condenser and again in a deaerating heater. Makeup will be introduced into the condenser to eliminate all possible sources of oxygen. It is proposed that ammonia be used for pH control with the possible addition of hydrazine as an oxygen scavenger.

A third source of contamination is makeup water. Demineralizing equipment is being installed to provide normal purity of 0.04 ppm with a maximum of 0.10 ppm. The design requirements are being determined through experience gained from a pilot plant at the Eddystone site, installed and operated by the Philadelphia Electric Company. Results to date indicate that such results are entirely feasible.

The solution of organic resins in the demineralizers is a fourth possible source of contamination. This will not be a problem in the case of the makeup, but there has been some experience indicating that it could become one in the case of the bypass demineralizer owing to the large volume of pure water passed through. This item is also being evaluated in a pilot plant.

To study the behavior of pure water and possible contaminants, two test boilers have been in operation. The first installation is in the laboratory of Sulzer Brothers in Winterthur, Switzerland Fig. 7. Furnace walls of an existing boiler were lined completely with a single tube coil designed to operate at 4260 psi and 1200 F outlet steam temperature. The unit is oil fired. Sampling connections were located at 20 to 30 ft intervals throughout the length of the circuit for measurement of pressure and temperature to permit washing deposits out of all or any portion of the circuit.

The variety of uses for such an installation for the development of information for the designer is almost unlimited. Some of the chief objectives of the experimental work have been to make these studies:

1. Formation of salt deposits in the tube system using synthetic feedwaters. This included study of the relationship between distribution of deposit and enthalpy, i.e., the location where deposit would be most likely to occur in a steam generating unit. A number of sodium and potassium salts were used separately and in combination.

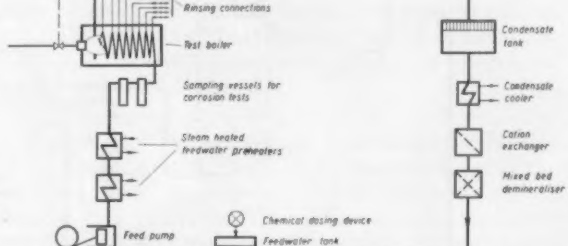


Fig. 7—Diagram of Sulzer test monotube steam generating plan for supercritical pressure

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[1] "Engineering the Eddystone Plant for 5000 psi, 1200 F Steam" by J. H. Harlow, ASME Paper No. 56-A-165.

2. Solubility of such salt deposits, or circumstances under which the deposits could be removed.

3. A study of the formation of deposits as steam expands through a simulated turbine.

4. Corrosion at supercritical pressure as influenced by temperature, water characteristics, and metal used.

5. Stability of water treating materials such as ammonia hydrazine and some of the volatile amines which have been used at lower pressures and temperatures.

Tests which have been completed with this installation confirm that, if deposits are to be avoided, solids must be eliminated from the feedwater. For instance, some of the sodium salts will deposit in the boiler circuit almost completely, the peak rate of deposit being at a temperature of approximately 900 F. Others will be deposited to a much lesser extent but with a similar pattern. Present indications are that very low pickup of metals can be expected in the high-pressure system, possibly due to the fact that alloy tubing has been used.

A second supercritical pressure boiler is in operation in the Kreisinger Laboratory in Chattanooga, Fig. 8, as a joint project with the Philadelphia Electric Company. Steam is generated at 5000 psig and 1200 F in a single-circuit boiler which is a scaled model of the Eddystone unit insofar as possible. Materials in the various sections are the same as well as the pressures, temperatures, and coefficients of heat transfer. The same water purifying system is used and supplies water to the boiler of the same purity and oxygen content. Steam from the boiler is passed through a simulated turbine consisting of several stages to study deposit formation as steam expands. The individual stages are formed by typical turbine blade sections with capillary tubing between each stage to provide selected steam conditions for each.

A contaminating vessel is located between the boiler and simulated turbine to study the solubility of various materials and determine the deposit pattern in the turbine. In addition to these tests, study is being given to the stability and effectiveness of chemicals that are being considered for water treatment. Much has already been learned about establishing procedures for removing dirt, grease, mill scale, etc., after erection to prevent later interference with operation of the unit. A complete boilout with phosphate and alkali is contemplated, followed by acid washing of the entire cycle with with the exception of the reheaters. The reheaters can be blown out with low pressure steam at high velocity through the turbine bypass system.

Although much has been learned from both of the programs described, it is planned to operate both units until all thoughts have been fully investigated.

Editor's Note:

The two companion papers, both on Eddystone, at this ASME Annual Meeting session on Supercritical Pressure were: "*Engineering the Eddystone Plant for 5000 psi, 1200 F Steam*" by J. H. Harlow, Philadelphia Electric Co. ASME Paper No. 56-A-165

"*The Eddystone Superpressure Unit*" by C. B. Campbell, C. C. Franck, Sr., and J. C. Spahr, Westinghouse Electric Corp. ASME Paper No. 56-A-156

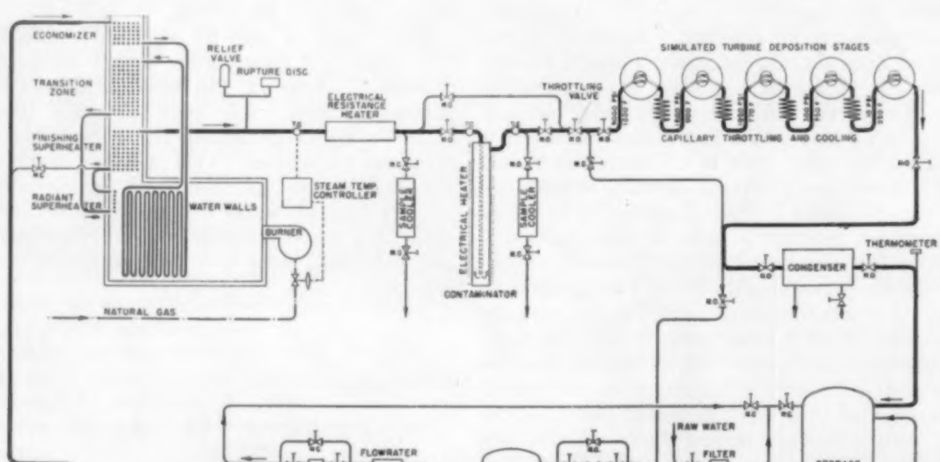


Fig. 8—Diagram of Chattanooga test boiler for supercritical pressure

ASME Annual Meeting in Review

The banquet—social highlight of the 77th Annual Meeting—brought together outgoing president, Joseph W. Barker, banquet speaker, Donald A. Quarles, incoming president, W. F. Ryan, and the Society secretary, C. E. Davies

SOME 5500 engineers from all over the United States and several foreign countries registered for the 77th Annual Meeting of the ASME held in New York City, Nov. 26–30 inclusive at the Statler and the Sheraton-McAlpin Hotels. More than 300 papers were presented at over 100 sessions in the five-day period.

The banquet, as usual, was the social highlight of the Meeting with Donald A. Quarles, secretary of the Air Force, serving as principal speaker. In the realm of Society business W. F. Ryan, vice president, director and senior consulting engineer, Stone & Webster Engineering Corp., was installed as president of the Society replacing Joseph W. Barker, president of Research-Cottrell Corp.

Also installed were technical director Eugene W. Jacobson, chief design engineer, Gulf Research and Development Company, Pittsburgh, and administrative director V. Weaver Smith, vice president in charge of contracts, Lummus Co., New York, N. Y.

Four regional vice presidents were named: William H. Byrne, president and chairman of the board, Byrne Associates, Inc., New York, N. Y.; James H. Sams, dean of engineering, Clemson College, Clemson, S. C.; Rolland S. Stover, owner, R. S. Stover Co., Marshalltown, Iowa; and Clifford H. Shumaker, chairman, Department of Industrial Engineering, Southern Methodist University, Dallas, Tex.

Nuclear Energy

A highly interesting two-session program was presented on the general subject of Design Progress in the Major Atomic Power Plants. These sessions each consisted of three papers describing prominent plants.

Glenn A. Reed, Yankee Atomic Electric Co., **Robert J. Creagan**, Westinghouse Electric Corp. and **Walter C. Woodman**, Stone & Webster Engineering Corp., combined to report on "The Yankee Atomic Electric Plant." The Yankee Atomic Electric plant is to be a pressurized light water reactor specifically for the production of 134 Mw net electrical power. It will produce 480 Mw of heat power. No other chemical or radiological functions will be performed at the facility. The reactor type is well known—a pressurized light water moderated and cooled reactor fueled with uranium oxide in the form of sintered pellets—and its chances for operating success are good in consideration of data accumulated under AEC and Naval programs. However, previous pressurized water reactor plants have generally stressed particular application or full-time reliability as major objectives. The major objective for the Yankee plant is to make the pressurized water reactor nearly commercially competitive with conventional steam plants, without sacrificing any of the inherent safety of this reactor type.

Conceptual design of the entire Yankee plant is in progress at CAPA (Westinghouse Corp.'s Commercial Atomic Power Activities). Stone & Webster is working on the site, transportation problems and plant layout and containment. It is not expected that many firm figures on the plant will be evolved before January 1, 1957, in view of the emphasis on economic optimization.

The Yankee schedule calls for major construction at the site to commence in the spring of 1957, although site preliminary studies (subsurface, meteorological and radiological) and land clearing are in progress. It is anticipated that construction will near completion by May 1960, and the system testing will be in progress. The reactor is expected to go critical in mid-1960, with power production on a reduced load schedule during the fall of that year.

The authors then gave rather detailed information and data on plant design, core design, fuel assemblies, controls, thermal and hydraulic design, fuel handling, shielding for the reactor section and some passing information on the turbine-electric plant.

J. R. Wolcott, V. A. Elliott, E. P. Peabody, G. M. Roy, J. L. Schanz and **G. Sege** of the General Electric Co., followed with their paper, "The Dresden Nuclear Station," a comprehensive design description. Since the design is 25 per cent complete, some design changes are to be expected in the future. Results of the design and accompanying development program to date give, in the authors' opinion, every indication of successful

operation of the 180,000-kw station. The plant is to be in service by 1960. Design started in April 1956; site construction is scheduled to start in early spring 1957.

Because conditions under which the project design is being carried out are somewhat unique from the standpoint of either normal utility practices or government sponsored nuclear projects, a brief review of the principal objectives are of interest: (1) The total power cost based on book value and operating cost is to be approximately equal to a conventional plant in this area. (2) Minimizing capital costs is a major concern. A primary aim of this undertaking is to contribute a maximum to the economic progress of a nuclear power industry. (3) The design must make adequate provision for public health and safety requirements. (4) Supporting development and design are proceeding in parallel. (5) The General Electric Co. has the prime responsibility for the design of this plant.

A steel sphere, 190 ft in diam, will enclose the reactor and associated auxiliaries to contain contamination in the unlikely event of a major nuclear incident. The turbine building, the irradiated fuel storage building, the administration building, control room and similar facilities will be located outside the sphere.

The dual cycle boiling water reactor was selected as the best solution to fulfill the design requirements, although other methods were considered. The dual cycle boiling water reactor, developed by General Electric, is a modified form of the direct boiling cycle pioneered by the Argonne National Laboratory of AEC.

In the direct cycle, steam is generated in the reactor container and sent directly to the turbine. The cycle is very simple in that it has a single loop, no heat exchangers and the turbine and reactor pressures are essentially the same. For use in large central stations, it was desirable to modify the direct cycle to improve: (1) the power output per unit of core volume and (2) the reactor response to load demand. Both of these objectives are related to the variation of nuclear reactivity with density changes caused by boiling.

The dual cycle approach is to remove as much energy as possible by boiling in the upper part of the reactor without exceeding the limit of reactivity for good stability. The boiling portion is controlled by the degree of subcooling at the inlet to the reactor. To accomplish this, the steam-water mixture is sent to a separating drum and the steam, essentially at reactor pressure, then flows directly to the turbine. The saturated water flows from the drum through heat exchangers where some energy is removed to produce steam at a somewhat lower pressure. This secondary steam is admitted to a lower stage of the turbine. The fraction of energy removed by means of the heat exchangers controls the temperature of the water returned to the reactor.

Load response is held to be good. The pressure in the reactor is held constant by the turbine regulating valve which controls the primary steam rate. Load changes are met by actuation of the secondary admission valves by the turbine governor. Decreasing the rate of secondary steam production results in higher temperature water returning to the reactor. This decrease in subcooling causes the reactor output to drop. For an increase in load, the reverse procedure is used. This self-regulating control feature causes the pressure in the secondary system to vary with load.

As would be expected the heat rate of the dual cycle is contingent upon the primary steam pressure and the percentage of power which is removed as primary steam.

John F. Anderson, Power Reactor Development Co., **Weymouth N. McDaniel,** Atomic Power Development Associates, Inc., and **Charles M. Heidel,** The Detroit Edison Co., then discussed the "Enrico Fermi Atomic Power Plant." The fast breeder type of reactor was chosen for this plant because of its good promise of providing an extensive source of economic electric power. Such a reactor offers the attractive possibility of utilizing low cost nuclear fuel in the form of abundantly occurring uranium-238 and thorium. The use of liquid sodium as the reactor coolant permits high temperature operation without encountering, at the same time, high coolant system pressures. Utilization of heat of fission at high thermal efficiency, therefore, can be attained.

In general, the core of a fast breeder reactor will be of relatively small size. The core of the reactor for the Enrico Fermi Atomic Power Plant is no exception and will consist of a uranium-molybdenum alloy, enriched to approximately 25 per cent with uranium-235. This enrichment is slightly more than 35 times that of naturally occurring uranium. Ultimately, all fast breeders are expected to use plutonium or uranium-233 as fuel, but both of these nuclear fuels are man-made, and neither fuel element technology nor the supply of these more desirable fuels is sufficient at the present time to permit the building of a large power reactor.

The cost of the Enrico Fermi Atomic Power Plant is estimated now to be $54,000,000. Of this amount $30,000,000 will be spent on the nuclear reactor and its auxiliaries, $14,000,000 will be spent on the steam electric generating facility and $10,000,000 will be spent on research and development and on business expenses during construction.

Much credit was given by the authors to the Atomic Energy Commission and the national laboratories for their interest and work on the fast breeder type of reactor. The fast reactor work that Argonne National Laboratory has done has been of great importance to both APDA and PRDC. There is a helpful interchange of information on design, physics, metallurgy and reprocessing between the AEC laboratories and APDA and PRDC. PRDC, in the furtherance of its project, will depend on the Commission for additional research and development assistance as set up in the Power Demonstration Reactor Program. This assistance has been requested specifically as follows: (1) That the Commission conduct in its facilities certain research and development work including the performance of a critical experiment and certain material irradiation tests. (2) That the Commission provide a reasonable amount of consulting service and assistance in the training of operating and maintenance personnel. (3) That the Commission supply the special nuclear material required and waive its use charges for a period of five years. (4) That the Commission furnish on a negotiated price basis all reprocessing services required, except the fabrication of core and blanket elements from raw materials.

The authors then supplied in the same manner as the above papers considerable information on the many considerations involved as well as much of the design details for the reactor, the steam cycle and the buildings.

The second session of this two-part exhaustive coverage of the nuclear power plants under way or under study was launched by **G. R. Milne,** Consolidated Edison Co., and **F. R. Ward,** The Babcock & Wilcox Co., with their paper "The Consolidated Edison Indian Point Nuclear Power Plant."

This plant, a nuclear steam electric generating station on the Hudson River, about 24 miles north of New York City, will have a reactor that will be a pressurized water, converter type and will be the first commercial unit to use thorium as the fertile material to supplement the base fuel uranium-235. The heat from the reactor would produce 140,000/kw of electric energy if it were not superheated. However, the saturated steam leaving the reactor will be superheated in separate oil-fired units resulting in a total capacity of 236,000 kw, in an appreciable decrease in the cost of the plant per unit of capacity and in a substantial decrease in the plant heat rate. Costs are given. The reactor system and its component parts are described and in addition those features of the remainder of the plant are covered which are important to reactor operation.

While the economics of superheating the saturated steam from the reactor having a temperature of 446 F at the turbine throttle to various temperatures, 860 F, 1000 F and 1050 F, were studied, only the most economic case is shown, namely that for 1000 F. The steam pressure at the throttle is reduced from 405 psig to 355 psig because of pressure drop in superheater and piping.

An examination of a table the authors provided showed that the addition of superheat to the cycle results in an increase in capacity from 140,000 kw to 236,000 kw and a reduction in cost from $322 per kw for a plant using only nuclear fuel to an average cost of $233 per kw for a combination of a nuclear boiler and separate oil fired superheaters. Since the rapid growth of the system load makes it necessary to continue building conventional steam generating units while obtaining experience in building and operating a nuclear unit, the cost of the incremental capacity gained by superheating before and after credit for lower heat rate may be compared with a cost of $200 per kw for new conventional generating capacity in New York City. The use of superheat will reduce the maintenance costs on the turbine as compared to a unit operating on wet steam throughout.

The authors pointed out, however, that if the relative costs of nuclear plants are sufficiently reduced in the future, or if the cost of nuclear fuel is reduced as compared with the cost of conventional fuels, or if superheating with the reactor to high steam temperatures of the order of 1000 F becomes possible, then superheating by means of a separate superheater using conventional fuels would be uneconomic.

A heat balance diagram was shown. In it the feedwater heating system consisted of four stages with three closed feedwater heaters followed by a deaerating type heater for the removal of oxygen. The heat rate for the steam cycle exclusive of reactor efficiency was said to be 10,700 Btu per net kwhr produced.

The reactor will be regulated to provide constant steam pressure in the boiler regardless of the load on the turbogenerator. This avoids the use of a main line pressure reducing valve which would otherwise be necessary if the reactor were controlled for constant reactor temperature. The reactor will also be designed so that load may be increased from 15 per cent to 100 per cent load over the period of a half hour and so that the load may be taken off the unit at the same rate. Operation below 15 per cent of full load is not contemplated because of reactor limitations. If the turbo-generator trips out or is taken out of service for minor reasons and the expectation is that the unit will be restored in a few hours, the reactor will be kept in operating condition and loaded to 15 per cent of capacity by means of a steam bypass around the main turbo-generator. By means of a pressure reducing valve and desuperheater in the bypass, steam will be passed directly to the condenser and the heat rejected to the river.

F. C. Gronemeyer, R. C. Gerber, H. M. Hagaman, H. B. Holz, H. A. Ross-Clunis and **E. F. Weisner** of North American Aviation, Inc., gave a paper on the "Proposed 75,000 Kw Sodium Graphite Reactor for the Consumers Public Power District of Nebraska." The Sodium Graphite Reactor (SGR) is a low pressure, high temperature liquid metal cooled system using solid fuel and solid moderator. This system is one of the original five major reactor types chosen by the Atomic Energy Commission for their power reactor development program. The SGR is felt to have both immediate technical feasibility and potential for future improvement. Among its more important features are:

(1) A high coolant temperature—925 F at present, is possible without requiring pressurization of the reactor heat extraction system. This permits good steam conditions and high thermal efficiency in the power conversion equipment.

(2) The reactor can be adapted to a variety of fuel elements and operating conditions. Both slightly enriched uranium or a thorium-uranium fuel may be used.

(3) There are no chemical incompatibilities in the fuel element, coolant, structure combination.

(4) The absence of releasable potential energy from pressurization or chemical reactions increases the inherent safety of this reactor system and permits the plant configuration to be easily arranged to contain radioactivity under all circumstances.

The sodium reactor experiment is a 20,000 thermal kilowatt pilot reactor, incorporating the major design features of a full scale sodium graphite reactor. Also included are the heat transfer systems, fuel handling system, instrumentation and control systems.

It was originally planned merely to dissipate the reactor heat through air-blast heat exchangers. However, the Southern California Edison Co. has recently been authorized to use this heat to produce electrical power. A complete steam generating plant has been installed with a capacity of 7.5 electrical megawatts, which Southern California Edison Co. will feed into its regular transmission lines and sell commercially.

The plant described in this paper follows the general specification of the 75,000 net electrical kilowatt power plant which has been proposed by Atomics International to the Consumers Public Power District of Nebraska. However, only the steam generating facility and the sodium reactor heat source were described.

The Pennsylvania Advanced Reactor Project, called the PAR, is a major development effort jointly sponsored by Westinghouse Electric Corp. and the Pennsylvania

Power and Light Co. Its function is to carry out the experimental and analytical studies leading to the design of an aqueous homogeneous reactor plant having an electrical output of 150,000 kw. This plant is to operate on the PP&L system in Eastern Pennsylvania and is planned to be in operation in 1962. **W. E. Johnson** and **D. H. Fax,** of the PAR project and **S. C. Townsend,** Pennsylvania Power and Light Co., described in their paper "The PAR Homogeneous Reactor Project." In many reactor types, the fuel, the moderator and the coolant are physically separate and distinct. In the aqueous homogeneous reactor they are all intimately mixed. The moderator carries the fissionable material in either solution or suspension and the whole circulates through a piping complex of reactor vessel, and a heat exchanger.

The reactor vessel is of such size that the quantity of fuel contained in it is equivalent to a critical mass and thus can sustain the fission process. The heated liquid is pumped to the heat exchanger where it gives up its heat to form steam in the secondary system and is then returned to the vessel to repeat the cycle.

In contrast to the fixed fuel type of reactor, the homogeneous system offers a number of important advantages. The problem of transferring heat at very high fluxes from fuel through cladding to coolant is obviated. Because of the absence of structural material within the core, more efficient use can be made of the neutrons born in fission. As the fuel is consumed, the fission products can be removed and fresh fuel added continuously, in contrast to the down time required by solid fuel reactors. Because fuel as well as moderator decrease in density with an increase in temperature, the homogeneous reactor can be inherently more stable with respect to power surges.

The PAR Project is concerned primarily with two homogeneous system types, the single region slurry reactor and the two region reactor. Both have excellent possibilities of being breeder reactors. Unfortunately, the information needed adequately to compare these two types of reactor plants does not exist today. The PAR Project Program is designed to develop this body of information, using that which is available from ORNL and other existing AEC programs and developing itself any additional information needed. The work falls naturally into three major categories. The first of these is the experimental program necessary to the determination of the physical and chemical properties of thorium and uranium slurries. The second category is that of the development of plant components. The third category of work embraces that of plant design and layout. Estimating the time required for developing the needed body of information in addition to the time required to design and construct the full scale plant, it was concluded that 1962 was the earliest date by which it could be hoped to have the plant in operation. These estimates allowed four years for the detailed design, construction and test operation of the plant so that by late 1957 or early in 1958 enough information from which to make a proper choice of the important plant design parameters should be developed. Today the project is 15 months old and half of Phase I program is behind the project's sponsors. The remainder of this paper described the work done to date and what must yet be done.

Discussion

Regarding the Yankee Atomic Electric Plant, it was pointed out that no special provisions were being made for cooling the containment sphere, which has been calculated to be self-cooling by radiation. The extensive use of stainless steel in the project was justified on the basis of dollar economy as opposed to the neutron economy obtainable from the use of zirconium with increased investment cost.

The Dresden Nuclear Power Station will be located on a 940-acre site which is bounded by a worked-out strip mine area to the south, an ordnance plant of large size to the east, and farming areas on the other sides. Two towns, each under 10,000 population, are located within a ten-mile radius. The reactor pressure vessel for this plant will be shipped from Camden, N. J., by barge.

Zirconium will be used in the metal-bonded fuel elements in the fast breeder reactor to be installed at the Enrico Fermi Power Plant. The diffusion-type bond will be one the order of 0.004 in. in thickness.

There was considerable discussion of the relation of fuel cost to total capital cost of nuclear power plants. At the Fermi Plant it was estimated that a single loading of fuel would involve an expenditure of about one third the total cost of the plant. Fuel in storage and in processing was not considered, and it was emphasized that the ratios of initial fuel costs to total plant investment would vary substantially with amount of burnup and methods of processing. At the Yankee Plant it was estimated that the cost of initial fuel loading would be between six and seven million dollars, or ten million dollars on two cores, in relation to a total plant investment of thirty-five million dollars. For Dresden Station it was stated that fuel costs would be about equal to fixed charges, based on the Commonwealth Edison method of capitalizing costs, and that the initial fuel investment would be about one third of the capital cost.

Valves and Piping

F. P. Fairchild, Public Service Electric and Gas Co. pointed out in the introduction to his paper, "Eight Years of Experience with Austenitic-Steel Piping Materials at Elevated Steam Conditions," that its purpose was to give perspective to the problems incurred with the use of heavy-wall, austenitic-steel piping for service at elevated steam conditions, from the standpoint of the user.

In three generating stations of Public Service Electric and Gas Co., austenitic-steel pipe is in service in the main steam systems of seven turbine-generator units, the first of which has been operating at elevated steam conditions since 1948. In all, there are now about 280 tons of this material in service in these stations. The record shows that there has been practically no trouble with this material, except at those locations where it is joined to other pieces of pipe, or attachements, by welding. In total, 517 principal shop and field welds were made in piping between boilers and turbines to put these systems together. Of these, 43 rewelds and 17 repairs were made in the first 174 joints; only one reweld and 4 repairs have been made in the last 343 joints. In the light of present knowledge, many of the 44 replaced joints could have been restored to soundness by repairing rather than complete rewelding. Of the fourteen stop valves installed, two forged valves have been replaced because of crack-sensitivity of the material. Except for some short spool pieces in the turbine leads of one unit, no other austenitic material has been replaced.

The experience of 8 years has proved the importance of the following techniques, which were available in 1948 when welding commenced on No. 1 unit at Sewaren Generating Station: (1) Complete avoidance of stress-raisers in the design of piping system components, including general pipe hanger attachments, thermocouples and any item which is to be welded to the piping system component. (2) Provision of ample flexibility in the design of the piping system and its supports. (3) Competent supervision to select, train and oversee the welding operators. (4) Careful inspection of the welds during the progress of the original welding.

During the 8 years, these new techniques have been developed by industry to improve the art of welding austenitic steels: (1) A first-pass welding technique that avoids use of a backing ring and results in a smooth contour on the inside of the pipe, free of cracks and stress raisers. (2) Closer control of chemical composition of the deposited weld metal with respect to ferrite. (3) The solution heat-treatment of welded joints in order to provide maximum ductility in the weld and heat-affected zones.

At the present stage of the development of austenitic steels for service at elevated steam conditions there are at least four areas, in the author's opinion, in which improvements are needed: (1) Better weld inspection techniques. Surer and less expensive inspection methods than are available today are required. (2) Matching properties of deposited metal and base metal. Means are required to match the properties of weld and base metal under all conditions of welding and operation. (3) Test to identify crack-sensitive material. A reliable test is required to show at an early stage of manufacture whether austenitic steel will or will not be crack-sensitive as finished pipe. Progress is being made in this direction in the Hot Ductility Test Program and other programs sponsored by the Joint ASTM-ASME Committee on the Effect of Temperature on the Properties of Metals. (4) Manufacture of noncrack-sensitive material. After the above work is complete the next obvious step is the development of manufacturing techniques to produce noncrack-sensitive material economically.

Relatively little information has been published on the resistance offered to laminar flow through valves and fittings. So **C. P. Kittridge** and **D. S. Rowley,** Princeton Univ., selected this area for research which they described in the paper, "Resistance Coefficients for Laminar and Turbulent Flow Through One-Half Inch Valves and Fittings." Carr and Schutz, the authors pointed out, tested globe and angle valves over the range of Reynolds' number approximately 1 to 10^5 and compared their findings with those of earlier investigators. Their paper contains a bibliography which has not been duplicated here. Beck and Miller and Beck reported tests on a variety of valves, fittings, and bends over the range of Reynolds' number approximately 30 to 1000. Beck reported a few losses for bends at low Reynolds' numbers which were less than the losses caused by equal lengths of straight pipe. This unexplained anomaly together with the general paucity of information for the laminar flow state prompted the program of research herein described.

A number of runs were made on a $^1/_2$-in. I.P.S. brass pipe with a piece of flanged straight pipe installed in place of a fitting. The friction factors obtained were shown and the agreement with the formulations of Poiseuille and Blasius, it was felt, provided a check on the apparatus and procedures. Similar tests for the long-radius-bend tangents attested to the accuracy of the pressure cell and potentiometer.

The authors gave several examples of their findings. As an illustration they reported the disturbance caused by a valve or fitting at $R > 2000$ could seldom be detected at any of the downstream pressure taps. Thus, the long downstream test section made possible a direct determination of the straight pipe loss for all such runs. Straight pipe losses were calculated for all runs at $R < 2000$ using $f = 64/R$. Resistance coefficients for a number of valves and fittings were given.

"Yesterday, Today, and Tomorrow—Pipeline Steels" was the topic chosen by **A. B. Wilder** and **A. F. Aebersold,** U. S. Steel Corp. The tremendous growth of the pipeline industry due to the increased production of oil and gas has greatly increased the production of line pipe. Early history and events which led to present-day practices in the manufacture of line pipe are outlined. With growth, new developments have occurred in the manufacture of line pipe which are described, and research work which will contribute to future development is also discussed. Welding characteristics of line pipe and the performance of pipeline materials in the field are discussed. The transportation of coal in the Pittsburgh Consolidation Coal Co. pipeline is described.

In this, a $10^3/_4$-in.-O.D. pipeline is being constructed for a distance of 108 miles between Cadiz, Ohio, and Cleveland, Ohio. The coal is being pumped as a water slurry and will be used for the generation of electrical energy in Cleveland, Ohio. API Specification 5LX Grade X42 C-Mn steel pipe in wall thicknesses up to 0.687 in. is being used with welded construction in the field. The coal will travel about 5 fps and will be 14 mesh and finer. Reciprocating pumps are being employed and the water will be treated with chromate and phosphate to inhibit corrosion. Absorption of free oxygen by the coal during transportation is one of the desirable features of the line with respect to corrosion. Sulfur in the coal is an undesirable feature.

The life of a coal pipeline, it is believed, depends upon the rate of corrosion and erosion from the coal-water slurry. The pipeline as planned, the authors state, will probably have a life exceeding 20 years. In order to determine the wall thickness periodically at various points throughout the line, the use of supersonic sound devices will be employed.

The coal pipeline provides a basis for obtaining knowledge concerning the transportation of solids at high speed in a slurry. One of the factors is turbulence and the elimination of the use of sharp bends reduced turbulence. One of the important applications for coal pipelines in the future will involve the transportation of metallurgical coal for coking purposes. The future possibilities of transporting other solids will only be limited by the technical attention which is applied. As this field develops, the steel pipe required may involve consideration of special abrasion-resistant materials. These special materials will be available, the authors are confident, as a result of research when they are required.

L. F. Coffin, Jr., spoke on "An Investigation of Thermal Stress Fatigue as Related to High-Temperature Piping Flexibility." This paper is a summary report of a cooperative research investigation extending earlier work on the thermal stress-fatigue resistance of AISI Type 347 stainless steel. The investigation was to provide additional qualitative experimental support of the concept of fatigue design based on an allowable stress range which is embodied in the ASA-B31.1 Code Rules for Piping Flexibility Design. Two specific objectives were established, together with the findings of this research. The objectives follow:

(1) Investigation of the effect of cycling which produces tensile rather than compressive stress under the hot condition. It was found that there was no significant difference.

(2) Investigation of the effect of reducing the net mechanical strain range for a given temperature extend to a point approaching the design strains for a piping system. While the temperature range was held constant, the trend of reducing the net mechanical strain range was to increase the number of cycles to failure similar to that obtained when the net mechanical strain range was reduced by lowering the temperature range under full constraint. In addition, for the same mechanical strain range, widening the temperature range decreased the number of cycles to failure.

"Pressure-Flow Characteristics of Pneumatic Valves" was presented by **F. D. Ezekiel** and **J. L. Shearer,** M.I.T. They explained that when a compressed gas is used rather than a pressurized liquid as the working medium in a fluid power-control system, the nature of the flow through orifice-type control valves is somewhat different from that which holds for liquid flows. The greatest difference is that the fluid density changes which occur in the case of a compressed-gas flow are many times greater than in the case of a liquid flow. Also, compressed gases usually have less density and much less viscosity than most liquids. In addition to the greater density changes which occur with gases for given pressure changes the velocity of sound in gases is much lower than that of liquids, and it is possible to attain sonic velocity in gaseous flow through an orifice when the pressure drop is about 50 per cent of the upstream pressure. Once sonic flow has been attained, any further drop in downstream pressure does not change the weight rate of flow through the orifice. Furthermore, it is more convenient in many cases to use weight rate of flow instead of volume rate of flow when dealing with pneumatic systems because the continuity and energy equations are more familiar to most engineers when expressed in terms of weight (sometimes called mass) rates of flow. It should be noted that temperature is an important variable in pneumatic systems since the density of the fluid is a strong function of both temperature and pressure.

Although, the authors maintain, it is in some ways more difficult to analyze the characteristics of pneumatic valves than it is to analyze the characteristics of hydraulic valves, a variable orifice is desirable for pneumatic power control because of about the same reasons that it is widely used in hydraulic power control. In addition, the presently available means of varying the rate of pneumatic power generation are slow and cumbersome as compared with variable-displacement hydraulic pumps.

In the paper, the pressure-flow characteristics are derived from equations that hold for frictionless flow of perfect and semiperfect gases.

Metals and Materials

Most published data for Type 347 stainless steel have been obtained for bar stock. The results described in the paper "Creep Characteristics of Type 347 Stainless Steel at 1050 and 1100 F in Tension and Compression, by **M. J. Manjoine,** Westinghouse Research Labs., are for specimens machined from a cold-drawn and stress-relieved seamless tube. The interaction of stress, strain, and temperature, causes metallurgical changes which alter the physical properties during service. In this investigation an attempt was made to determine the nature of these metallurgical changes and their effect on the elevated-temperature strength characteristics for both tension and compression loading.

Other investigators have noted abnormal creep behavior in stainless steels at elevated temperatures. Smith, et al., reported that either annealed Type 304 or 316 stainless steel tested at elevated temperatures gave a false minimum creep-rate period shortly after loading. They attributed this abnormality to structural changes during tests. The structural changes were believed to be associated with the precipitation of carbides, ferrite, and sigma. Freeman, et al., also noted the abnormally low creep rate at short-time periods and attributed it to the formation of sigma volume decrease accompanying the precipitation reaction. The Timken Roller Bearing Co. reported anomalies in creep rate for specimens from a heavy-wall, Type 347, stainless-steel tube.

Cold-drawn and stress-relieved Type 347 heavy-wall tubing flows plastically at service temperatures (1050–1100 F) when subjected to a stress below the 10,000-hr rupture strength. Precipitation induced by the strain and temperature conditions causes an extended period of abnormally high creep resistance. The duration of this period increases with decreasing stress and is longer for compression than for tension. The creep and rupture strengths for service duration over 10,000 hr are poorer than those reported for Type 347 annealed bar stock.

Diesels, Engines and Compressors

A. K. Antonsen, Fairbanks, Morse & Co., supplied some interesting material on "The Development of Supercharged Medium Speed Two-Cycle Opposed Piston Engine." By 1952 it became apparent that the conditions for the development of a commercial supercharged, two-cycle, opposed-piston engine had been favorably improved. One major improvement consisted of the turbocharger manufacturer's ability to produce turbochargers of higher overall efficiency. This supercharging could serve a twofold purpose; namely, greatly increased engine rating, together with substantially reduced fuel consumption.

It was kept in mind that two-cycle supercharging would require a much closer matching of engine and turbocharger throughout the load range than what is required for four-cycle engines. Unlike four-cycle super-

charging the two-cycle engine has no natural breathing mechanism which can perform an air-intake stroke when the turbocharger capacity falls off.

It was realized that the best possible fuel economy could be obtained by eliminating or at least limiting the parasitic power requirement of the engine-driven blower. An improved turbocharger efficiency also could be expected to aid in this purpose. It was realized that the manifold design could be instrumental in obtaining optimum performance.

The experimental development has to date covered four individually different systems of supercharging.

It is believed that the following facts have been established: (1) The supercharging of the two-cycle, opposed-piston engine can be accomplished with manufacturing simplicity and operational dependability equal to or exceeding the four-cycle engine. (2) The best fuel economy of the supercharged two-cycle engine is seemingly inherently better than four-cycle supercharged fuel economy. (Experimental tests have proved a 0.333 lb/hp-hr possible for this medium-speed engine.) (3) Major sudden load variations between 50 per cent and full load can be handled on a self-sustained basis without the aid of auxiliary-blower equipment. Starting and minor sudden load changes can be handled without the aid of auxiliary-blower equipment.

P. J. Louzecky, Cleveland Diesel Engine Div. of General Motors Corp., followed with his paper on "Design and Development of a Two-Cycle Turbocharged Diesel Engine." The successful turbocharging of two-cycle diesel engines, Mr. Louzecky stressed, has been a desirable goal for many years. Although various attempts were made by diesel-engine designers to solve the many problems involved, a satisfactory solution was not forthcoming until suitable turbochargers had been developed with pressure ratios from 2:1–3:1. Recently, however, very rapid progress has been made and the excellent results obtained, reflected by nearly doubled engine output and much improved economy with only nominal increase in size and weight, more than justify the development efforts expended.

Yet the development of a successful design of two-cycle diesel engines for turbocharging involves many difficult problems, such as integrating the turbocharger to the engine, developing an exhaust manifold that will result in a minimum loss of heat energy and making the engine components sufficiently rugged to carry the increase in engine loads. A solution to these problems, obtained by intensive study and testing, is presented in this paper. Also described, are the favorable results achieved, which are improved fuel consumption, increased engine horsepower and decreased engine size per horsepower as compared with nonturbocharged two-cycle diesel engines.

Fuels

"Competition, Substitution, and Demand Among Fuels" by **Paul W. McGann,** U. S. Bureau of Mines, was written to give cognizance to the fact that economic factors must necessarily be considered in evaluating any proposed engineering application. One type of economic relationship which has not been used as much as it should in this connection is empirical measurement of the demand for fuel. This situation doubtlessly has been due largely to the inconvenience faced by individual analysts in developing such data, since such work often is foreign to their primary interests. The present paper is intended to help redress the balance by providing some preliminary and illustrative data on these relationships. The data are taken from studies under way in the Bureau of Mines.

The author commented that a simple and useful sort of demand relationship exists between the logarithms of a ratio of consumption over income and a ratio between prices. The advantage of using relations in logarithms is that the slope of a straight line fitting the data is the useful "elasticity coefficient" between the two sets of data. The term "elasticity" is used in economics to denote the ratio of a proportional (or percentage) change in one variable to a proportional change in the other. Such a ratio is independent of units of measurement and thus is very useful in comparing many different sets of data. Another advantage in using logarithms is that adjustment for incomplete samples is not necessary if the sample proportion of the population is constant.

The customary procedure for estimating elasticities of demand is to follow the "least-squares" method. As a first example of statistically estimated elasticity of demand Mr. McGann took the competitive elasticity of bituminous coal used for national electric power generation. The price ratio in question was formed by dividing the average cost of coal to electric utilities (a substitute for price) by the weighted average cost of fuel oil and natural gas. The consumption ratio was coal used in electric power generation divided by Gross National Product in constant prices. The resulting competitive elasticity was -1.9. If, instead, the author suggested, one took as a price ratio the average costs to electric consumers of coal (per Btu) divided by average costs of oil and gas as the price ratio, the price elasticity is -1.5. This actually is the more representative value because of the closer relevance of the prices to the consumers in question; and the amount of the difference of elasticity values is interesting to note as a deviation that can be obtained by using plausible alternative price concepts. The elasticities discussed in generalities were shown in table form.

Mr. McGann then discussed other elasticities of demand for other fuels, for various sections of the country and concluded with the hope that the technique discussed would prove helpful.

W. H. Attwill and **C. D. Day, Jr.,** E. I. du Pont de Nemours & Co., together with **A. J. Johnson,** consulting mechanical engineer, presented a paper on "Evaluating Coal by Utilization Cost." In a company such as du Pont, the paper pointed out, large quantities of coal from a wide range of coal fields are burned in virtually all types of combustion equipment. Thus, one of the major problems was a single program that could be made company-wide in scope and application, and yet cover all local conditions to the best advantage for each plant.

Further, the program should be of continuous and lasting benefit to the individual plants. The full scope of this program which the authors cover in their paper produced a plan (1) sufficiently flexible to offer optimum

results to widely scattered plants drawing from wholly dissimilar sources of coal supply,

(2) capable of selecting coals fully suited to the individual requirements of the particular plant to which they were to be consigned,

(3) practical enough to allow evaluating coals on a basis of their actual worth, or "utilization cost," at the point of firing; that is, after giving full consideration to such factors affecting steaming costs as Btu, moisture, ash, grindability (in pulverized plants), and fine coal content (in spreader-stoker plants),

(4) simple enough to permit a continuous check upon all coals offered, to determine whether they meet the requisite conditions and to ascertain their relative "utilization cost,"

(5) extensive enough to include a sufficient number of coals to insure a representative coverage of all potentially economical sources of logical supply,

(6) sound enough to allow periodic checks of plant costs to determine whether the program is operating as planned and to ascertain whether optimum results are being secured,

(7) broad enough so the plant's coal specifications will provide reasonable latitude for obtaining the widest range of coals for economical purchasing while satisfying operating requirements.

The authors then described much of the mechanics they went through in determining the ways and means of instrumenting this program. Finally, though, they ran into an unexpected barrier—how to translate the apparent savings to dollars and cents.

It was obvious that they had to have some kind of a coal-price index, corrected at least for Btu, before they could obtain a true picture of savings determinations. Governmental agencies and coal associations were contacted but no readily available information was found that would apply in this particular case. The Bureau of Labor Statistics does maintain a nationwide coal index, but it cannot be broken down into coal-producing districts.

Thus, it was decided that such an index to be both dependable and up to date must originate with the du Pont Company. To this end, an index was set up for a certain group of plants drawing from the same general coal mining area, against which monthly operating costs would be readily compared. This index is based on the average of several well authenticated coals used by these plants for which both mine price and Btu data were continuously available.

This coal index is a straight price average of the several coals, with each coal first being corrected to a 28,000,000 Btu ton. The index was developed on a monthly basis and carried back to a period of one year prior to the start of any of the fuels programs. A comparison of actual plant costs to the index then gives saving or loss.

Gas Turbines

W. A. Sherbrooke, Piping Specialties, Inc., and **H. Monroe, Jr.,** Newport News Shipbuilding & Dry Dock Co., in their paper, "Air and Gas Duct System for the Gas-Turbine Vessel, *John Sergeant,*" described the Liberty ship S. S. *John Sergeant* which was converted by the Maritime Administration at the Newport News Shipbuilding and Dry Dock Co. to gas-turbine power from its original reciprocating steam engine design. This was done as part of a Liberty Ship Conversion and Engine Improvement Program. The overall plant, the authors related, is well described in J. J. McMullen's paper presented before the Society of Naval Architects and Marine Engineers.

This paper describes the ducts, dampers, and expansion joints of the inlet-air and the exhaust-gas system for the gas turbine installed on this Liberty ship. The system involved is for a regenerative cycle with a waste-heat boiler. As could be expected the limitations of space and allowable loads on terminal connections of equipment resulted in major problems in duct and expansion-joint design. The solution to these problems is described. An expansion joint was tested and a comparison is given of calculated and actual loads.

J. S. Grobman and **R. T. Dittrich,** National Advisory Committee for Aeronautics, supplied considerable data on "Pressure Drop and Air Flow Distribution in Gas-Turbine Combustors." In the design of combustors for turbojet and ram-jet engines, the authors explained, it is desirable to be able to predict the combustor total pressure loss and air flow distribution from the combustor geometry and operating conditions. Low values of combustor total pressure loss are desired because these losses reduce engine thrust and cycle efficiency. Further, air flow distribution is of direct interest to the combustor designer because it influences combustion efficiency and stability and combustor outlet temperature profile.

The calculation of combustor total pressure loss and air flow distribution for a given combustor design is a tedious and time-consuming problem and the need exists for generalized curves that can be used to obtain preliminary estimates of combustor total pressure loss and air flow distribution. These curves would also be useful in indicating the relative effects of combustor geometry and operating conditions. This report is concerned with the development of such generalized curves for tubular combustors having (1) constant annulus and liner cross-sectional areas along the combustor axis and (2) flush circular holes in the liner walls. The results may apply approximately to can-annular and annular combustors having equal velocities in the inner and outer annuli at all points along the combustor axis. The combustor total pressure loss coefficient and air flow distribution are presented graphically in terms of certain dimensionless parameters.

Hunt Davis, Worthington Corp., in his paper "Equivalent Performance Parameters for Turboblowers and Compressors" explained that, in general, turboblowers and compressors are built for a specified set or sets of performance conditions and the attainment of the specified performance is often checked by carefully conducted tests made in the manufacturer's shop or in the field.

Frequently it is not possible to duplicate all of the specified independent quantities and a strong need is evident for incorporating in the ASME Power Test Code for compressors a suitable means for planning tests and correlating data by use of some parameters of equivalence.

The purpose of this paper is to show that under certain conditions, compressor performance data obtained with

one test gas and set of test conditions may be related to another set of specified conditions with either the same or another gas, and with assurance of accurate correlation.

In other words, the use of a different test gas and other different test operating conditions does not necessarily prevent the attainment of similitude of operation with regard to a specified set of operating conditions.

The author then gave a set of conditions which are functions of the independent variables that he believed necessary and sufficient to establish equivalence of sets of operating conditions for a compressor when the individual independent variables differ. The conditions apply to the individual compressor elements, to individual stages, to groups of stages and thereby to the whole machine.

If the six conditions cited can be fulfilled when a test point is being related to a design-point set of specifications, the test engineer can be assured that all flow and dynamic phenomena, including windage and leakage effects, have been reproduced.

Automatic Dispatching

D. H. Cameron and **E. L. Mueller,** Kansas City Power & Light Co., combined forces to describe "A New Type Automatic Dispatching System at Kansas City." The objective of any load control scheme for successful interconnected system operation, in the authors' opinion, should be to provide: (*a*) means for absorbing load changes within the control area on the maximum number of units possible so as to maintain frequency and net interchange on interconnections at scheduled values, and (*b*) means for assigning sustained load changes within the control area to the units based upon a prearranged set of loading curves to effect maximum economy of operation.

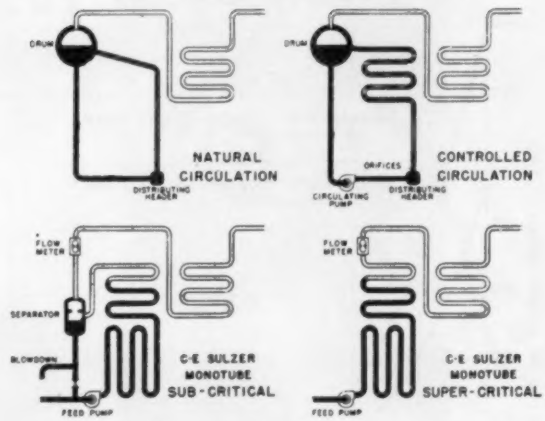
The first objective has to do with regulation. Since the normal load changes in any one control area of a large interconnection have very little effect on system frequency, some form of supplementary control must act upon the governors in that area to cause them to adjust for the load change. The commonly accepted method of control is Tie Line-Bias wherein the signal to the respective governors is proportional to the deviation of tie from schedule and of frequency from normal. This supplementary regulation action can be likened to the combined governor action on an isolated system not having supplementary control.

The second objective has to do with economy of operation. If a control system performed a regulating function only, system economy would suffer. Constant readjustment of unit loadings would be required of the operators to even approach economical operation. The greater the number of stations and units involved, the more difficult it would be to attain maximum economy by manual means.

In 1953 an extensive study was made of the load control requirements of the authors' company system with a view to solving the regulation problem occasioned by the addition of the large arc furnace load and extension of interconnected operations and, at the same time, to selecting a control system which would approach the optimum in operating economy. The system chosen, the problems involved, and a brief account of a typical operating period were presented in this paper.

The growth of the electric utility industry has occasioned advances in the art of steam generator design and operation with attention centered on continuous operation of large units. One controlling factor in this respect is proper water conditioning. With the standardization and simplification of units and the improved makeup quality, water treatment for high pressure boilers is becoming more standardized, states the author. The paper discusses design of modern boilers with emphasis upon general circulation, problems and goals for water treatment, and, finally, basic treatments that are giving good results today.

PRINCIPLES OF CIRCULATION



Water Treatment for Boilers—Natural Controlled Circulation, Once-Through*

By R. C. ULMER

Combustion Engineering, Inc.

IN preparation for a discussion of goals for water treatment, consider the basic boiler designs sketched above. In the upper left is natural circulation in which water is separated from the steam in the steam drum and recirculated through the water wall section. Circulation is established through the system as the result of a "head" established by the difference in density of the fluid in the riser and downcomer sections. This type of boiler has been successfully used for many years for pressures below 2000 psig. Above 2000 psig, it is desirable to "assist" the circulation through the water walls and any convection surface by use of circulating pumps. Orifices at the inlet of tubes and circuits assist in the uniform distribution of water. This is known as controlled circulation and is shown in the upper right. In addition to improving circulation, this design makes possible smaller diameter tubes in the furnace with less wall thickness and consequent lower metal temperature.

Some idea of the boiler water concentration for natural and controlled circulation boilers can be obtained from the American Boiler and Affiliated Industries' limits shown in Table 1.

The once-through principle as used in CE-Sulzer monotube design below critical pressure is shown in the lower left of sketch. Immediately following the evaporation section is a water separator. This removes the small residue of moisture, 4 to 5 per cent, in which most of the solids have concentrated. A portion of this water is discharged as blowdown and the remainder is returned to the feed pump suction. Feedwater for this type of unit must be of high quality, concentrations of the order of 1 to 2 ppm having been used satisfactorily. Lower concentrations may be required to prevent turbine deposits.

With pressures above critical, there is no place in the circuit where water and steam of markedly different densities exist. Consequently no drums or separators are used. The CE-Sulzer monotube design for supercritical pressures is shown at the lower right. All of the water entering a circuit passes out as supercritical fluid. As no solids are "separated," a somewhat more pure feedwater is required than for subcritical pressures; one with total solids under 0.5 ppm generally is required.

General Problems

Carryover—Natural and Controlled Circulation Boilers

Two types may be encountered, entrainment of boiler water and vaporization of silica. The American Boiler and Affiliated Industries limits for foaming, one of the chief causes of entrainment, have just been revised and are shown in Table 1. It will be noted that emphasis is placed on total solids, alkalinity and suspended solids. Other constituents, "oil, grease and other foam inducing materials," require attention and for all intents and purposes should be absent.

Vaporization of silica occurs at a rate dependent largely on temperature and pH of the boiler water. Assuming a pH of the order of 10.8, for a given pressure, and therefore, temperature, a certain maximum concentration of SiO_2 is permissible in the boiler water. The limits generally followed are given in Fig. 2. Obviously since the curve refers to total allowable silica in the steam, if mechanical carryover or entrainment is occurring, less silica can be tolerated in the boiler water.

With the higher pressures and temperature of modern

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* Presented at the Fall Meeting, Pennsylvania Electric Association, Prime Movers Committee, Hicksville, L. I., October 18, 1956.

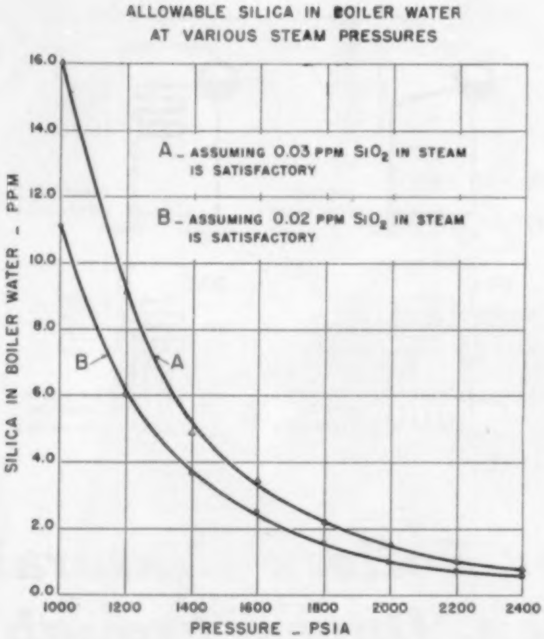

Fig. 2—Allowable SiO_2 values in boiler water for various steam pressures

boiler operation, there is evidence that materials other than silica vaporize in appreciable quantities. For example iron deposits are found in turbines and chlorides are found in steam and condensate. Mechanical carryover or entrainment accounts for some of the amounts found but vaporization may contribute. This subject is being investigated.

Carryover—Ce-Sulzer Subcritical and Supercritical Pressure Once-Through Boilers

In the case of subcritical pressure once-through boilers the purity of the steam from the separator is governed largely by the solids concentration of the feedwater. Silica control generally is no problem as feedwater of the desired purity will have a sufficiently low silica concentration, say, 0.02 to 0.03 ppm. As no "separation" takes place in supercritical pressure boilers, desired limits are set for each constituent in the feedwater.

Deposits

There are two general sources of deposits: (1) mineral impurities usually from condenser leakage, and (2) oxides from preboiler corrosion. With improvement of condenser design and fabrication, the problem of condenser leakage has not been very serious with natural and controlled circulation boilers. Mineral deposits certainly have been of little concern. Where silica deposits are a problem or where limits to prevent vaporization are required, blowdown of boiler water is practiced and some work has been done with bypass demineralizers in the condensate system (1)[1].

In the case of subcritical and supercritical pressure once-through boilers, consideration also is being given to

TABLE I. AMERICAN BOILER AND AFFILIATED INDUSTRIES LIMITS FOR BOILER WATER CONCENTRATIONS IN UNITS WITH A STEAM DRUM

PRESSURE AT OUTLET OF STEAM GENERATING UNIT LB PER SQ. IN.	TOTAL SOLIDS PPM	TOTAL ALKALINITY PPM	SUSPENDED SOLIDS PPM
0 - 300	3500	700	300
301 - 450	3000	600	250
451 - 600	2500	500	150
601 - 750	2000	400	100
751 - 900	1500	300	60
901 - 1000	1250	250	40
1001 - 1500	1000	200	20
1501 - 2000	750	150	10
2001 AND HIGHER	500	100	5

" The COMPANY shall not be responsible for carryover resulting from the presence of oil, grease or other foam inducing materials."

condenser leakage, and as will be brought out later, steps are being taken to guard against it.

In the case of all four types of boilers, preboiler corrosion leading to deposits is one of the most serious problems. The corrosion is due to low pH and/or dissolved oxygen in the preboiler system. A recent paper by Grabowski, et al. (2), discusses this problem in detail, indicating oxide sources throughout typical systems.

The problems from oxide deposits, or, for that matter, from any deposits, are twofold. They may cause overheating of heat transfer surfaces, leading to failures. Another type of failure involves concentration of boiler water salts beneath or throughout the deposit. Sufficiently high concentrations result so that the metal reacts, forming magnetic iron oxide and hydrogen. Penetration of the metal may take place, or the hydrogen may enter the metal, embrittling it. Decarburization of the metal at the point generally occurs. A typical example is shown in Fig. 3. It will be noted that metal temperatures are "normal."

As this type of failure involves a deposit and attack beneath it, the question of proper boiler water circulation often arises. Actually, it is difficult to determine exactly why a deposit forms where it does, but failures of the above type definitely have been found where metal temperatures were normal within the limit of measurement. Experimental data indicate that marked concentration of boiler water can take place with even a few degrees temperature above saturation (3). This readily can be obtained at metal surfaces "insulated" by oxide deposits. As will be brought out later, cases of this type have been eliminated by acid cleaning to remove present deposits and then eliminating new ones through the use of proper preboiler treatment

Corrosion

One type of attack, that due to concentrated boiler water beneath deposits, was discussed in the previous section. Other types of corrosion or metal attack that may occur may be characterized as (1) general and (2) localized or pitting.

General attack results from low pH, say, below 7.0, and needless to say, therefore, is seldom encountered in present-day practice. Pitting generally is associated with dissolved oxygen although low pH may greatly accelerate it. An example of this type of corrosion is shown in Fig. 4. The pit occurred near a weld in a water wall tube. An iron oxide deposit often occurs near the pit. The problem in this and several other similar cases, has been

[1] Numbers in parentheses refer to similarly numbered listings in the References carried at the end of the article.

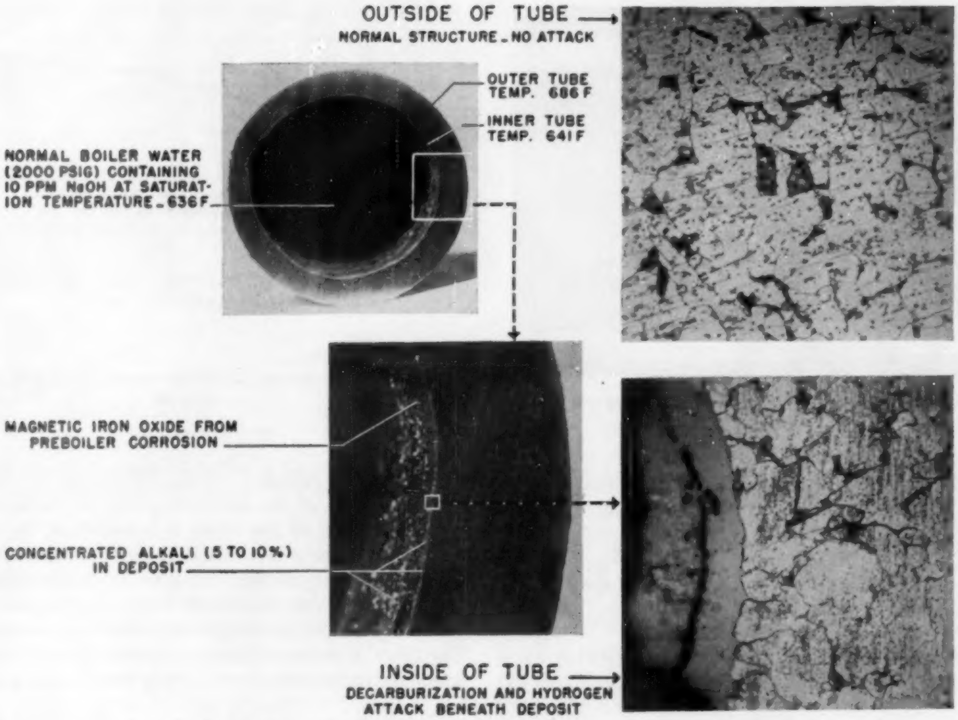

Fig. 3—Examples of attack upon metal lying beneath an oxide deposit

entirely eliminated by lowering the dissolved oxygen and maintaining a sodium sulfite excess in the water (4).

The fact that corrosion can take place while a boiler is not operating often is disregarded. In fact serious corrosion can take place during and immediately after the draining period. Corrosion initiated in this way may serve as foci for further corrosion during operation and the roughened surface is more likely to gather deposits than a smooth one.

Some plants employ special draining techniques, for example, draining the boiler while it is hot and blowing air through it to promote drying (1). This eliminates moisture which otherwise would cause rapid attack of the metal.

Serious corrosion also can take place while the boiler is standing idle filled with water, for example, before it is put into operation and during outage periods. Filling the units completely with water containing about 100 ppm hydrazine and applying a slight pressure, say with nitrogen, has been found to eliminate this problem.

If corrosion occurs the products should be removed. Acid cleaning of the boiler initially and as required during service satisfactorily eliminates this problem.

Caustic Embrittlement

Intercrystalline cracking or caustic embrittlement seldom found in present-day operation, occurs generally along riveted seams or crevices at tube ends. As practically all joints in high pressure boilers are now welded there is little chance of this occurring. As the possibility of embrittlement still exists in some older boilers, the subject merits some consideration.

There are three factors necessary for intercrystalline cracking of boiler metal: (1) leakage of the boiler water must take place so as to permit escape of steam and concentration of the boiler water at the point of leakage, (2) the boiler metal must be subjected to high stress and (3) the boiler water must possess embrittling characteristics. The first two are difficult to evaluate; the third is the basis of a test (ASTM D807–52) used to determine whether preventive means should be taken. In this respect as there have been very few cases of caustic embrittlement in modern utility boilers, very few utilities use a preventive method.

Specific Treatments

Natural and Controlled Circulation Types

As only 10 to 25 per cent of the entering feedwater is converted to steam in any circuit, there is ample circulating water to carry the solids, and, therefore, a considerable concentration of solids can be tolerated. As mentioned, carryover generally is the limiting factor and Table 1 gives the American Boiler and Affiliated Industries' limits.

Two general types of internal boiler water treatment are applicable: one involves maintaining low causticity and the other establishing a so-called zero causticity or captive alkalinity.

For low causticity type the following limits or controls apply:

Alkalinity......................OH, about 5 ppm (pH about 10.8)
Phosphate....................3 to 5 ppm as PO_4

Fig. 4—Tube failure due largely to dissolved oxygen

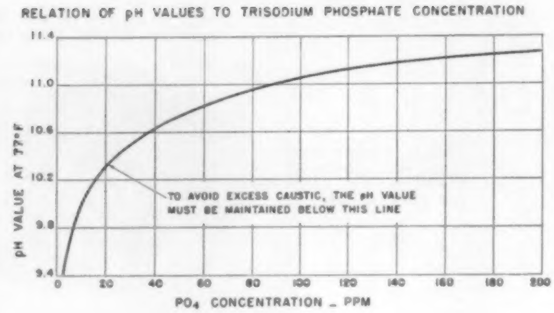

Fig. 5—Zero causticity curve for coordinated pH-phosphate control

Reducing agent................	3 to 5 ppm Na_2SO_3, or slight excess of N_2H_4
Silica..........................	as per Fig. 2
Solids..........................	as per Table 1

This might also be referred to as a minimum treatment as the amount of solids added to the system is about the minimum possible. It probably is the most widely used system in the utility field. Where used with proper preboiler treatment excellent results are being obtained.

Some investigations have indicated the desirability of carrying a somewhat higher alkalinity as a protection against pitting especially at stressed areas (5). Our experiences have indicated that this is not necessary provided the dissolved oxygen is under control and a reducing agent is used.

For zero causticity type the following limits apply:

Alkalinity....................	PO_4, about 20 to 100 ppm* (pH about 10.8*)
Phosphate....................	as per alkalinity requirement
Reducing agent................	3 to 5 ppm Na_2SO_3 or slight excess of N_2H_4
Silica..........................	as per Fig. 2
Solids..........................	as per Table 1

* NOTE: pH - PO_4 plot must fall on curve, Fig. 5.

The relation of pH and phosphate concentration must be such that only trisodium phosphate is present in the boiler water. This relationship is shown in Fig. 5. Adjustments in treatment are made so that the plot falls on the curve. The method sometimes is referred to as the coordinated pH - phosphate control (6).

There being no appreciable free hydroxide present in the boiler water, the chance of caustic embrittlement or attack beneath deposits is minimized. The method requires means and considerations for both raising and lowering the alkalinity, and possibly for this reason has never been used to the extent of the low causticity type.

CE-Sulzer Once-Through Type—Subcritical Pressures

In most of the designs, some of the tubes run with some superheat and in the remainder the average water to steam ratio is about 1 to 25. With the relatively low water content of the mixture going to the separator, a smaller portion of the solids is retained in the separated water (7). These facts are taken into consideration in determining the type feedwater to be used and they also influence the type treatment used. As to treatment the general principle of using only volatile materials applies. The two CE units of this type under construction will use a feedwater and treatment along the following lines:

Total solids....................	0.5 ppm maximum
pH..............................	8.8 to 9.2
Hydrazine......................	slight excess
Dissolved oxygen...............	0.007 ppm

Some ammonia will be produced by decomposition of the hydrazine. This will be insufficient to raise the pH to the desired limit and additional ammonia as such will be added.

Good quality makeup available from demineralizers and evaporators is used for these systems. Condenser leakage is kept at a minimum. Modern condenser designs show promise of very little contamination.

Metal pickup in the system is kept at a minimum by procedures outlined later.

CE-Sulzer Once-Through Type—Supercritical Pressure

The same general considerations as for subcritical once-through type units apply to the supercritical pressure units. The three CE supercritical pressure units under construction will use a feedwater within the following limits:

Total solids....................	0.25 ppm (0.5 ppm for short periods)
pH	9.0 to 9.5 (by N_2H_4 and NH_3)
Total iron......................	0.01 ppm
Total copper....................	0.01 ppm
Silica..........................	0.02 ppm
Dissolved oxygen...............	0.007 ppm

As mentioned, this treatment essentially is the same as for subcritical once-through boilers except the limits for solids are somewhat lower. Therefore, again pure makeup, low condenser leakage and low metal pickup, will be insured. It is probable that actual units will operate with lower solids than indicated above.

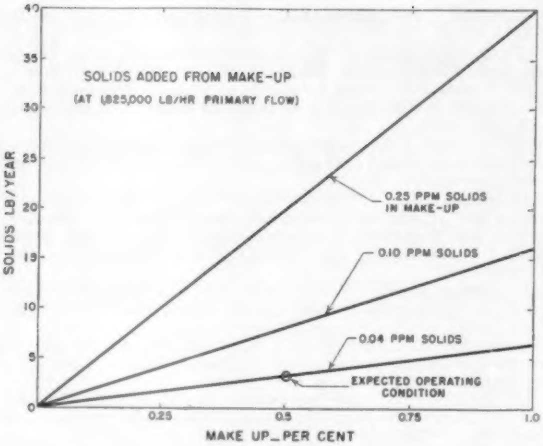

Fig. 6—Amount of solids entering a boiler system from various quantities of makeup of different purities

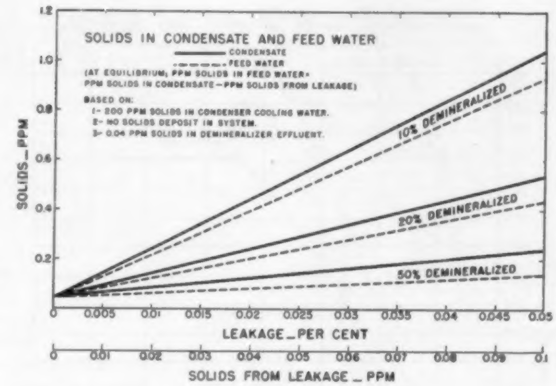

Fig. 7—In event of leakage bypassing various portions or the total condensate through a demineralizer produces these results

Some idea of the amount of solids entering the system for various amounts of makeup of different purities is shown in Fig. 6. With low makeup of the order of 0.5 per cent, little solids will be added even with relatively impure makeup, say 0.5 ppm. On the other hand, as shown in Table 2, even a trace of condenser leakage will add a significant amount of solids. This emphasizes the need for condenser designs such that leakage will be negligible or the use of purification systems for removing solids. As mentioned condensers with negligible leakage are anticipated. Should some leakage occur the effect of bypassing various portions or the total condensate through a demineralizer is shown in Fig. 7. It will be noted that the system can be maintained in a satisfactory condition by this means even though there is significant leakage.

Metal pickup will be controlled in the usual manner; that is, by pH control and eliminating of dissolved oxygen. A slight excess of hydrazine will be added as a reducing agent. This will also supply some ammonia for pH control and the remainder will be applied as such.

Metal Pickup in Preboiler System

This probably is the most serious problem in modern boiler water conditioning and therefore merits further emphasis. It has been discussed in papers by Grabowski (2), Powell (8), Ristroph (9), Straub (10), Sperry (11), Ulmer (12), and others.

It should be borne in mind that "pure" water, such as condensate, makeup and feedwater for the boilers under consideration, can dissolve a considerable amount of iron, copper and other materials with which it comes in contact. Such dissolved material often amounts to several hundred pounds per boiler per year. For example, only 0.01 ppm iron in the feedwater to a 2,000,000 lb per hr boiler will result in 175 lb of iron being carried into the boiler per year. Many plants operate with much more iron and, for that matter, copper in the feedwater, so much more is carried in. If this material deposited evenly over the boiler metal system, no problems likely would occur, but unfortunately, deposits have a habit of accumulation at particular locations leading to overheating or more often to concentration of the boiler water salts to a point where metal attack occurs beneath the deposit. The remedy is very simple: (1) maintain a pH of 8.8 to 9.2 throughout the preboiler system, (2) maintain dissolved oxygen at a low value, say 0.007 maximum and (3) maintain an excess of reducing agent, sodium sulfite or hydrazine, in the system (13).

High Pressure-High Temperature Water Problems

Temperature ares gradually creeping up, which centers attention on selection of materials that will stand up and not contaminate the water. With the advent of supercritical pressure boilers, other questions, for example solubility of salts in the supercritical fluid, also arise. These subjects were dealt with recently in a paper by Partridge (14).

Some of the questions raised in the Partridge paper rapidly are being clarified. For example, Fig. 8, from the work at Battelle shows that common alloys can be expected to give good service even at 1350 F (15). The AEC has sponsored work involving corrosion tests with pure water at elevated temperature. The results of this work also indicate that materials having very low corrosion rates are available and can be used (16), (17).

From a more practical standpoint, considerable investigation work has been carried out or is under way in test boilers. Previous reference has been made to the Babcock and Wilcox work (18), and to the CE-Sulzer program (19), in Switzerland. This work also has indicated no unusual conditions to be expected in the operation of supercritical pressure units at high final temperatures. Further assurance of these points is being ob

TABLE 2. SOLIDS ADDED TO SYSTEM BY CONDENSER LEAKAGE*

PPM SOLIDS FROM LEAKAGE	PER CENT LEAKAGE	LB WATER LEAKED / HR	LB SOLIDS ADDED TO SYSTEM PER HOUR	PER DAY	PER YEAR
0.001	0.0005	6.34	0.001	0.03	11.1
0.005	0.0025	31.70	0.006	0.15	55.5
0.010	0.0050	63.40	0.013	0.30	111.0
0.025	0.0125	158.50	0.032	0.76	277.7
0.050	0.0250	317.00	0.063	1.52	555.4
0.100	0.0500	634.00	0.127	3.04	1110.8
1.000	0.5000	6340.00	1.270	30.04	11108.0

*Note: Assuming 1,268,000 lb/hr condensate and condensing water solids of 200 PPM

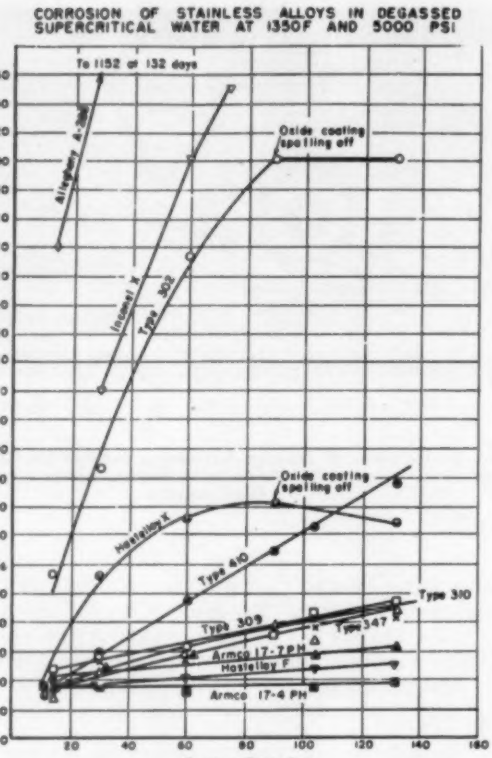

Fig. 8—Battelle Memorial research work into corrosion of various alloys by high temperature, supercritical water is pictured in graph above

tained in a joint investigation now under way between the Philadelphia Electric Company and Combustion Engineering, Inc. with a 5000 psi, 1200 F test boiler. Results to date indicate very low metal pickup with the metals used and the water treatment followed.

The latter program involves a 5000 psi, 1200 F boiler followed by a simulated turbine. Between the two is a "contaminator" where metals and salts to be studied can be placed. It is planned to run for approximately1000 hours without treatment. This will give a measurement of the metal pickup. Various treatments will be tried then in similar runs in an effort to cut down the metal pickup. Observations will be made regarding the stability of the treating materials.

This general subject will be covered in a future paper.

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Founder Societies Vote To Keep Headquarters In New York City

UNITED Engineering Trustees, Inc., the joint corporate agency of the four major national engineering societies, has signed a contract for preliminary architectural plans and studies for a new Engineering Center in mid-Manhattan, New York City. This is the first definite step toward construction of what is expected to make New York the "engineering capital of the world."

Announcement of the granting of the contract came with announcement of the re-election of Walter J. Barrett, of Glen Ridge, New Jersey, as President of United Engineering Trustees, Inc. (UET). It was, also, the first formal revelation that all the four member societies of UET, and a fifth that is expected to become a member, had voted, through their governing boards, to remain in New York. Several other cities had sought the Center.

Architects Chosen

The architects named are Shreve, Lamb and Harmon Associates, of 11 East 44th Street, New York, designers of the Empire State Building and more recently the new Brooklyn Supreme Court Building. The announcement did not indicate any details as to specific location, cost or completion.

The present 16-story quarters, known as the Engineering Societies Building, house the four "Founder Societies," the American Society of Civil Engineers, the American Institute of Mining, Metallurgical and Petroleum Engineers, The American Society of Mechanical Engineers and the American Institute of Electrical Engineers. A fifth prospective "Founder Society," the American Institute of Chemical Engineers will be included in the Center project. At a recent meeting at which Mr. Barrett was re-elected and the architectural contract granted, the Board of Trustees of UET approved the American Institute of Chemical Engineers as a member. This action awaits ratification of the other four Societies.

The American Institute of Chemical Engineers now is located at 25 West 45th Street. Occupants of the Engineering Societies Building include Engineers Joint Council, which is composed of ten major national engineering societies, including the five in the "Founder" group.

It is believed that preliminary plans will be completed early next year. The inclination toward a mid-Manhattan site is due to appreciation of accessibility of railroad and airline terminals and convention hotels.

Financing Plans

Financing is expected to run into "several million dollars." In addition to the contributions of the various "Founder Societies" and their members, UET, which has been charged with the responsibility of the planning, construction and financing of the new structure, has received assurances of the cooperation of a group of industrialists and educators toward the required fund. This group, headed by Dr. Mervin J. Kelly, President of Bell Telephone Laboratories, Inc., stated on June 8, 1955, in a letter to UET and its constituent societies, its readiness to assist in this direction on the selection of a city following a broad and careful study of all possible sites with national rather than local interest to be the determining factor.

Mr. Barrett was elected President of UET last year when the new Center project had reached a high state of discussion. His re-election continues his direction of the biggest program of UET since it was created in 1904, at which time Andrew Carnegie presented the present Engineering Societies Building as a suitable union home for the profession. Mr. Barrett is transmission maintenance engineer of the New Jersey Bell Telephone Company, Newark. He represents the American Institute of Electrical Engineers on the UET Board of Trustees and is Treasurer and a Director of the Institute. He is also a Director of EJC.

Official Statement

In a statement announcing the granting of the contract, Mr. Barrett said:

"It is the sense of UET that the new Engineering Center presents a challenge to the profession. Engineers have planned, designed and constructed outstanding structures of all kinds throughout the world. Now the profession faces the challenge of building for itself a Center that will reflect the profession's dignity and stature. It is not likely that the genius and imagination that have gone into the building and rebuilding of the modern world will fail to create in this instance an appropriate testimonial to the profession.

"The new Engineering Societies Building will, as is true of the present quarters, contain more engineering organizations than any other building in this country. It will have, indeed, more than any other building in the world. Our present quarters have been crowded for years. As memberships and activities have expanded the need for greater space has become increasingly pressing. The new Center will make possible its occupancy by societies not able now to find space in the present quarters.

"UET was established 52 years ago 'to advance the engineering arts and sciences in all their branches and to maintain a free public engineering library.' It owns the Engineering Societies Building. Through the Engineering Foundation, it conducts research in engineering and scientific subjects for the advancement of engineering and for the good of mankind. The library is the largest of its kind in this country and works closely with the New York Public Library, the Library of Congress and other institutions. UET acts in a fiduciary capacity for a large number of joint activities of the major engineering societies.

"As it became evident in recent years that the present quarters were inadequate, many cities pressed to have the new Center located in their communities. All these were given full consideration. A Special Task Committee of Fifteen, three from each of the five societies directly concerned, directed a study by an independent firm of management consultants and this Committee several months ago made recommendations which were presented to the governing boards of the five Societies. The governing boards have voted to approve the recommendation to remain in New York."

The June 8, 1955 letter, signed by 21 men eminent in their fields of industry, engineering, science and education, gave assurances, in the matter of financing the new Center, that "a well-organized, diligent and competent effort will be made and continued until the required sum is available." The letter urged the designation of independent management consultants to make a thorough-going study of all considerations in the offers and invitations of the several cities. The letter emphasized that "we are agreed that the fundamental desirability of approaching this matter on a national rather than a local basis transcends our personal preferences." The letter said further, in part:

"The progress of our highly industrialized society is dependent on its scientific and technologic strength. A major portion of the technology upon which our industries depend is encompassed within the combined scope of your Societies, and a large portion of the professional men contributing to the technology and its practice are members of one or more of your organizations. It is because of the important place in our society that you occupy that we are concerning ourselves with the choice of a location for your new headquarters."

The signers stated that "the long range interests of the Societies in serving their professions and the nation are paramount" and that "maximum effectiveness of your operations is of controlling importance."

The letter went on to say: "Most industries of the country benefit directly from the technologies included in your organizations. We are sure they will contribute generously to your building funds if your location is chosen on the broad-gauged basis suggested. If such a choice is made, a group of the undersigned will organize a large national committee, representing all sections, all technologies in your Societies, and a variety of industries, to conduct a nationwide drive for funds."

Signers Listed

Besides Dr. Kelly, the signers were: James F. Bell, Minneapolis, Chairman, Committee on Finance and Technological Progress, General Mills, Inc.; Detlev W. Bronk, Washington, President, National Academy of Sciences; Ralph J. Cordiner, New York, President, General Electric Company; Jame Creese, Philadelphia, President, Drexel Institute of Technology; Jess H. Davis, Hoboken, New Jersey, President, Stevens Institute of Technology; Lee A. Du Bridge, Pasadena, California, President, California Institute of Technology; T. Keith Glennan, Cleveland, President, Case Institute of Technology; Eugene G. Grace, New York, Chairman of the Board, Bethlehem Steel Corporation; Crawford H. Greenewalt, Wilmington, Delaware, President, E. I. du Pont de Nemours & Company; William H. Harrison, (since deceased) New York, President, International Telephone and Telegraph Corporation.

Also, Livingston W. Houston, Troy, New York, President, Rensselaer Polytechnic Institute; Frederick L. Hovde, Lafayette, Indiana, President, Purdue University; Kaufman T. Keller, Detroit, Chairman of the Board, Chrysler Corporation; Horace P. Liversidge, (since deceased) Philadelphia, Chairman of the Board, Philadelphia Electric Company; John L. McCaffrey, Chicago, President International Harvester Company; Alfred P. Sloan, Jr., New York, Chairman of the Board of Directors, General Motors Corporation; Charles A. Thomas, St. Louis, President, Monsanto Chemical Company; Martin D. Whitaker, Bethlehem, Pennsylvania, President, Lehigh University; Robert E. Wilson, Chicago, Chairman of the Board, Standard Oil Company of Indiana; John D. Wright, Cleveland, President, Thompson Products, Inc.

McKinsey & Company, management consultants, surveyed all factors involved in the possibilities advanced by the several cities and recommended

New York. In a report on June 22, 1956, forwarded to the governing boards of the Societies, the Special Task Committee of Fifteen reviewed the considerations involved and urged that mid-town New York be approved.

It was suggested that if the present site proved to be not feasible another location in mid-town be chosen. The proposal required approval of each of the Societies. The final approval was voted recently.

Besides Mr. Barrett, officers elected by UET for the next year are: 1st Vice President, Willis F. Thompson (Vice President, Westcott & Mapes, Inc.); 2nd Vice President, Andrew Fletcher (President, St. Joseph Lead Company); Treasurer, Joseph L. Kopf (President, Jabez Burns & Sons, Inc.); and Assistant Treasurer, George W. Burpee (Partner, Coverdale & Colpitts).

New Books

Any of these may be secured by writing Combustion Publishing Company, 200 Madison Avenue, New York 16, N. Y.

Symposium on Basic Effects of Environment on the Strength, Scaling and Embrittlement of Metals at High Temperatures

ASTM Special Technical Publication No. 171, 120 pages, $2.75

Since most of the creep and creep-rupture tests from which design data on high-temperature alloys can be obtained are carried out in normal atmospheres, and since most high-temperature materials are used in atmospheres of water vapor or some products of combustion, the design engineer must always be concerned with the effects of the environment upon the creep rate and the ductility of the materials that he uses.

It was with the hope of contributing to the understanding of these effects that the General Research Panel of the ASTM-ASME Joint Committee on Effect of Temperature on the Properties of Metals decided to sponsor this Symposium which was held at the 1955 ASTM Spring Meeting in Cincinnati. It was felt that there must be data on oxidation and surface effects and on creep under controlled atmospheres that the panel could collect in one publication, and that by so doing further work in this field would be stimulated. It is believed that the papers which make up this Symposium represent accurately the status of the problem of environment at the present time.

Symposium on Metallic Materials for Service at Temperatures Above 1600 F

ASTM Special Technical Publication No. 174, 200 pages, $3.50

The demand of engineers to attain greater efficiency in heat engines has created a need for metals to withstand the increase in operation temperatures. Steam power plant design engineers are pushing temperatures and operating pressures beyond the safe operating limits of the ferritic steels now in use, and the gas turbine engineers (and those concerned with devices such as guided missiles) are prepared to design for operation at temperatures higher than the 1600-F limit to which they have been confined for want of materials capable of satisfactorily withstanding higher temperatures of operation. This Symposium, sponsored by the General Research Panel of the ASTM-ASME Joint Committee on Effect of Temperature on the Properties of Metals, attempts to provide a basis of evaluation of a number of metallic materials, including cermets, which have been undergoing study in laboratories both here and abroad, to determine their suitability for higher temperature service. The papers, which were presented at the 1955 ASTM Annual Meeting in Atlantic City, discuss as many as possible of the properties—physical, chemical and mechanical—as well as methods of combating surface deterioration that are affected by temperature. The paper-bound publication includes 14 technical papers and a transcription of discussion made at the time of their presentation.

Specifications and Tests for Electrodeposited Metallic Coatings

ASTM, 104 pages, $1.85

This compilation of 17 specifications, methods of test, and recommended practices embodies the work of ASTM Committee B-8 on Electrodeposited Metallic Coatings. These ASTM Standards in the field of electrodeposition of metals have either been developed jointly with the American Electroplaters Society, or have had subsequent endorsement by this group. The last issue of the B-8 compilation was October 1953, and since that time all but 5 of the 17 standards have been

revised. Many of the revisions have been based on extensive research projects within the committee, including long-time atmospheric exposure tests of copper-nickel-chromium plated steels.

The book contains specifications for zinc, cadmium, nickel-chromium, and lead on steel; nickel-chromium on copper; nickel-chromium on zinc; and chromate finishes on zinc coatings. In addition there are recommended practices for preparation of low-carbon steel, high-carbon steel, zinc-base die castings, and copper-base alloys for electroplating; chromium plating on steels; and preparation of and electroplating on stainless steel and aluminum alloys. Methods of test include test for local thickness and two spray tests—the salt spray (B 117) and the acetic acid-salt spray (B 287).

Elevated Temperature Properties of Carbon Steels

ASTM Special Technical Publication No. 180, 68 pages, $3.75

This is the fourth publication in a current series prepared under the auspices of the ASTM-ASME Joint Committee on the Effect of Temperature on the Elevated Temperature Properties of Metals. This series was started so as to incorporate in one book the available elevated temperature data on a particular "family" of metals.

This "carbon steel compilation" includes data for tensile and yield strength elongation and reduction of area, stresses for creep rates of 0.0001 and 0.00001 per cent per hour and rupture strengths for 100, 1000, 10,000 and 100,000 hours.

The steels covered are killed carbon steel (0.18 to 0.24 C), ASTM A 201 Grade B plant steel (0.24 C max), ASTM A 106 Grade B pipe steel (0.30 C max), killed carbon steel (0.27 to 0.58 C), aluminum killed steel, open steel (rimmed or capped), and miscellaneous carbon steels (limited data available).

The properties are given in graphical form and supplemented by copies of original data sheets from those contributing the data.

Plant Operators' Manual

By Stephen Elonka

McGraw-Hill, 292 pages, $5.00

This book, based on material published in *Power*, shows steam engineers, plant mechanics, and other power services personnel how to maintain and operate equipment, giving methods and pointers which will be of help in daily work and in future upgrading and license examinations. A major feature of the book is its sequence illustrations, with each operation shown step-by-step in photographs or line drawings.

Boilers, steam engines, turbines, diesel engines, pumps, compressors, and similar equipment are covered. A wide range of practical materials is provided, covering such jobs as setting valves of a steam engine, charging a Freon compressor, overhauling a bearing, and timing and setting diesel engine valves.

The book also tells how to use the most recent maintenance tools, the reflectoscope for detecting cracks in metal and the deflection gage for finding misalignment in large diesel crank bearings.

The author is Associate Editor of *Power*.

Guide to Instrumentation Literature

By W. G. Brombacher, Julian F. Smith, and Lyman M. Van der Pyl

National Bureau of Standards Circular 567, 156 pages, $1.00, U. S. Government Printing Office, Washington, D. C.

This circular is intended to assist research investigators, instrument users, and others interested in utilizing the extensive and scattered literature of instrumentation. It was prepared as part of the program of instrumentation research and development which is cooperatively sponsored at the National Bureau of Standards by the Atomic Energy Commission, the Office of Naval Research, and the Air Research and Development Command. Over 1200 references are listed, including abstract journals, bibliographies, 660 books on technology, directories of manufacturers, guides to and indexes of technical literature, periodicals of interest, and guides to dissertations, patents and specifications. Articles published in periodicals are not referenced, but indexes and abstracts of such articles on a given subject are indicated in the subject index.

Panel Discussion on Pyrometric Practices

ASTM Special Technical Publication No. 178, 78 pages, $1.50

Much interest centers in defining the precision of temperature measurement and control which can be recommended or specified in high-temperature test work. The Panel Session, organized by the Test Methods Panel of the ASTM-ASME Joint Committee on Effect of Temperature on the Properties of Metals, discusses work in this field, and is concerned with the ASTM recommended practices on high-temperature testing of metals, E 21, E 22, and E 85. The papers were presented at the 1955 ASTM Annual Meeting at Atlantic City and include the following:

Thermocouple Immersion Errors, by J. M. Berry and D. L. Martin, General Electric Research Laboratory.

Summary of Pyrometric Procedure Employed by One Company in Creep-Rupture Testing and an Analysis of Results Obtained, by W. E. Leyda, The Babcock & Wilcox Co.

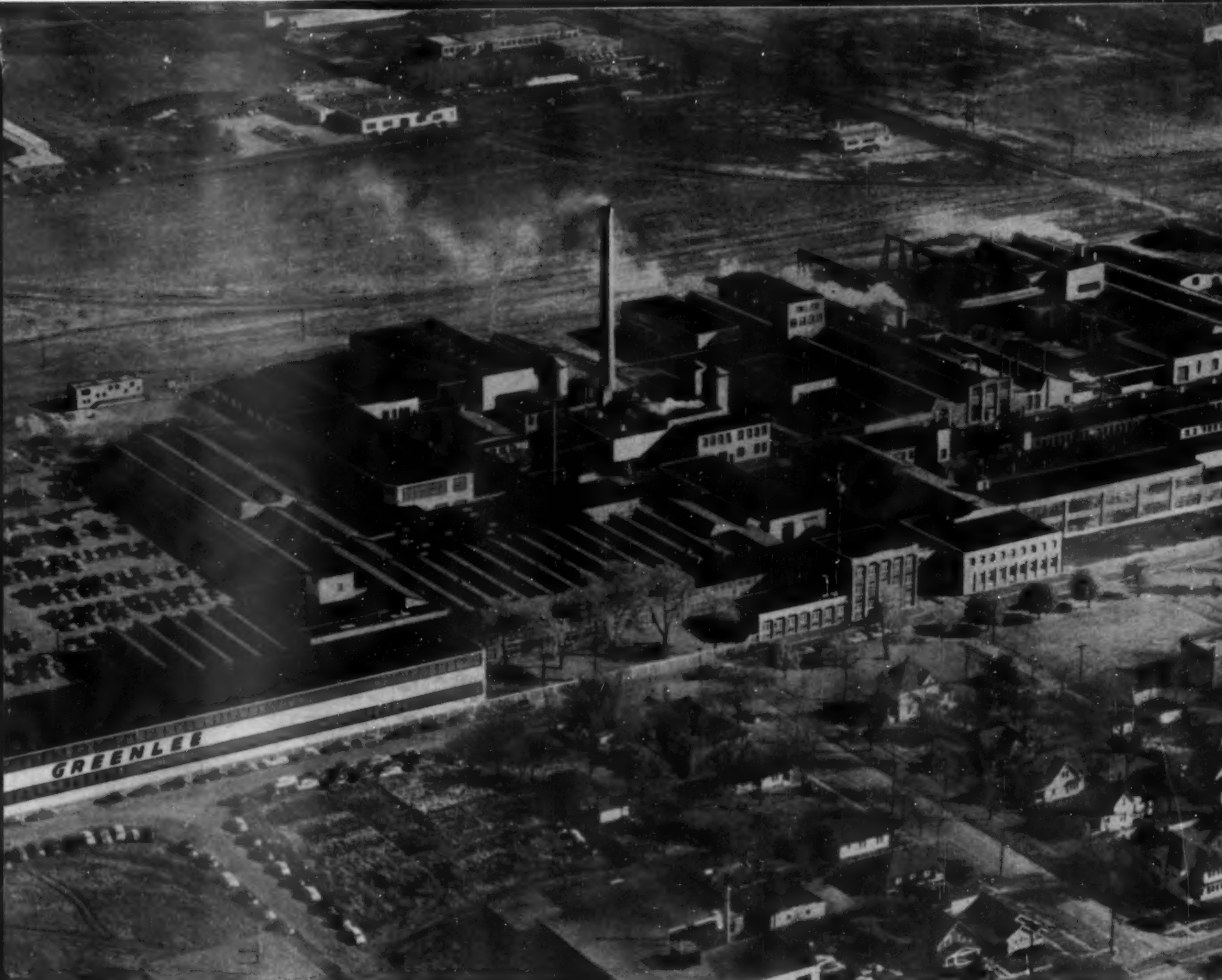
Creep and Rupture Test Pyrometry, by Charles R. Wilks, American Brake Shoe Co.

The Mechanical Properties of Wrought Phosphor Bronze Alloys

ASTM Special Technical Publication No. 183, 120 pages, $3.00

This paper shows the effect of cold-working on the mechanical properties of a series of eight phosphor bronze alloys in two conditions in the form of cold-rolled strip with varying tin content from 0.5 to 10 per cent. Electrolytic tough pitch copper strip similarly treated is included to provide a base for evaluating the effectiveness of the tin.

The mechanical properties—including tensile strength, proportional limit, yield strength at both 0.01 to 0.2 per cent offset, modulus of elasticity, —are reported for six different tempers of each of the materials.



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Expanding facilities at Greenlee Bros. & Company, Rockford, Illinois, created a problem common to many growing firms. The Company's three old boilers had to operate continually at maximum capacity, so that a forced outage could hurt plant production. In addition, peak load operation with outmoded equipment resulted in high fuel costs.

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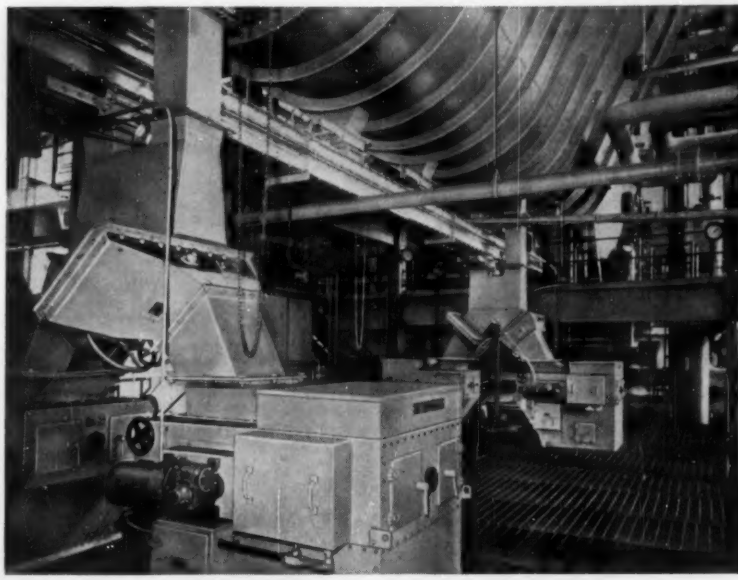
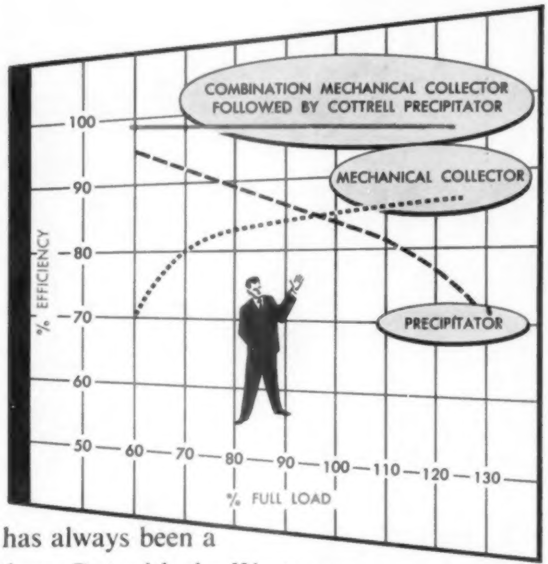
(*Continued on page 75*)



Advantages of the Western Precipitation CMP Unit

for recovering fly ash in power plant operations



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From these years of experience gained in *both* electrical (Cottrell) and mechanical (Multiclone) recovery installations, Western Precipitation pioneered another new development—the CMP Unit—*a unit that combines in one compact installation many of the best features of both electrical and mechanical recovery methods.*

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This arrangement offers several important advantages. Removing the heavier particles by Multiclone permits the bulk of the recovery operation to be performed with relatively low-cost equipment. Using a Cottrell for the final clean-up insures unusually high recovery efficiency—approaching theoretically perfect, if desired. Thus, the CMP combines high recovery efficiency with low total cost.

But that's not all. The CMP has the further advantage that the efficiency curve of the Multiclone portion complements that of the Cottrell portion (as shown in the chart above)—*therefore the overall CMP efficiency remains practically uniform at all boiler loads.*

At low boiler loads the recovery efficiency of the Cottrell is highest . . . and at high boiler loads the Multiclone reaches its maximum efficiency. But, by combining the two types of equipment into a *single* CMP Unit, the efficiency curve remains almost flat, regardless of the boiler load.

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